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PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

JULY, 1943
Vol. 22, No. 7

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GRADY TRIPLETT
Editor

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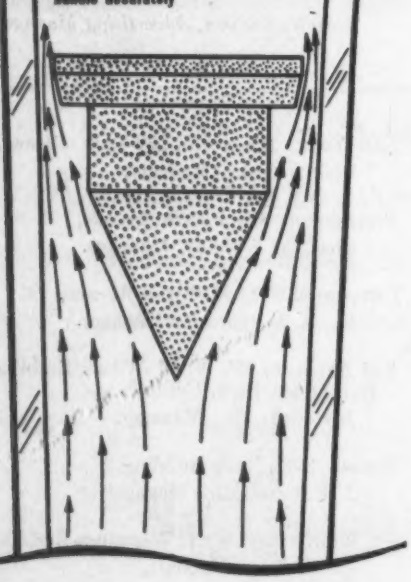

DURING the last two years a definite reversal of trend in the development of meters for rate of flow measurement has become noticeable in industry. The area-type flow meter, in the form of the rotameter sight flow meter, has steadily and surely elbowed its way to the front. Already it has completely replaced the head-type meters (orifices, flow nozzles, venturis, weirs, capillaries) for many important applications and the process of replacement is still going on.

The inherent theoretical advantages of the area-type flow meter have always been recognized, and equally obvious were the several limitations of the head-type meter. Yet for a long time the area-type meter was mainly a curiosity, used only for unusually difficult applications. Not until Fischer & Porter Company in 1937 announced the availability of precision-bore, interchangeable transparent metering tubes for rotameter sight flow meters, did the area meter start to progress.

In Toricelli's equation $Q = CA\sqrt{2gh}$, the area-type meter (rotameter) obtains measurement by varying the value of "A" (area of flow passage) whereas head meters vary the value of "h" (head producing flow). Thus the rotameter "gets out from under the square-root sign," which results in a linear calibration scale instead of a square root scale crowded at the lower end. The range of flows which can be accurately metered with the rotameter is thereby tremendously increased.

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Possibly you have used the rotameter sparingly, or not at all, because you have not realized its basic worth. The further one delves into the details of the rotameter functioning, the more advantages come to light. Modern instrumentation is characterized by an acknowledgment of these advantages through the increasing use of the rotameter for flow rate measurement and control. Our bulletin #10-A entitled "A New Trend in Flow Rate Measurement" describes the rotameter clearly and concisely. It contains free, valuable information — why not write for it? We will gladly send it to you without any obligation whatsoever.

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RATE OF FLOW INDICATING, RECORDING OR CONTROLLING ROTAMETERS FOR ANY LIQUID OR GAS

VOLUME 22, NO. 7 JULY, 1943

PETROLEUM
REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

A GULF PUBLISHING COMPANY PUBLICATION

THE LOOK BOX

OF ALL human deficiencies, none is so stifling as lack of faith. This embraces more than religion, for loss of confidence, doubt of natural laws or distrust of the imagination are all attitudes that amount to poverty of spirit. Lack of confidence is more damaging than lack of material things. Confidence will stimulate until ingenuity and invention can find a solution for absence of materials.

Poverty Of Spirit

Just now, led by the chorus in Washington, the fact of a depleting oil supply is being shouted in all the keys of pessimism. Statistics are convincing that over a period oil has been consumed in greater quantities than it has been found, and every indication is that this will continue. This is a serious situation. More serious, however, is the acceptance of this situation as assurance of disaster.

Since there is no proof to the contrary, it is accepted that oil no longer is being created by nature. If true, the supply of oil has been growing less from the day the first drop was burned. Over this span there have been periods when discovery exceeded consumption, followed by periods when consumption exceeded supply. Strangely enough each has been accepted as calamity.

There may be no more, one more or a dozen oil deposits such as East Texas. Whatever the number, no man can change it. Men of vision, however, may do something about the fact that as yet science has found no instrument or method by which a structure like East Texas can be outlined.

Only the poor in spirit accept a diminishing oil supply as defeat. What it amounts to is a challenge. Science needs new tools, products of imagination, research and development.

For all the praise showered on refining technology and automotive engineering, their accomplishment in the internal-combustion engine is little short of economic crime. Less than a tenth of the energy released from a gallon of gasoline can be translated into road travel. More than 70 percent of the heat set up has to be dissipated in keeping the motor cool enough to operate.

It may or may not be true that oil consumption will continue to surpass oil discovery as measured by present standards. What men of vision can do is to so change the recovery of energy that a gallon of gasoline will do more useful work. Something can be done about that, but it will not be done by men who are looking backward.

Exhaustion of oil is not exhaustion of energy. Fortunately there is no evidence to support the fear of energy exhaustion. There are indications of the exhaustion of forms in which nature has stored energy, as in oil or coal. However serious this prospect, it does not compare with an attitude whereby men lose the courage to seek new storage reservoirs of energy or more efficient uses of energy already at hand. That is truly poverty of spirit.

WHEN a process such as hydrogen fluoride alkylation finally becomes commercial there is an inclination to look upon the development as having been compressed within the few months that preceded completion of the first plant. Along with the scientific information from the two articles by Professor J. H. Simon, "Hydrogen Fluoride — The Catalyst," it is worthwhile to recognize that the subject

For the Record

had a long and consistent laboratory record prior to commercial development.

Bibliography of the two articles, the last being in this issue of PETROLEUM REFINER, included 48 references. Certainly laboratories, especially the one at The Pennsylvania State College, was busy on hydrogen fluoride long before commercial success. In paying tribute to the petroleum industry, other laboratories and the equipment industry, Professor Simon makes this plea, which should have consideration:

"Encouragement and support for the work from these industries would be both welcome and appreciated."

Right and Obligation

ALL too often it seems that the good old American privilege of going on strike is interpreted as an obligation to quit the job for minor causes. The refining industry had such an instance in June. Two men became involved in an altercation. One was dismissed. The plant was shut down for two days.

Wherever men work there will be differences and the result will be dismissals. That has been going on since industry brought men together for cooperative effort. Only recently, however, has the complete group accepted such events as a personal altercation as grounds for a strike.

Men should realize that the strike weapon will retain its edge far longer if it is little used.

Still Silent

EVIDENTLY military authorities prefer inadequate gasoline supply over inaccurate estimate of demand. At least the petroleum industry still has no official word as to the demand for aviation motor fuel in months to come. Supplying an unknown demand is something of a handicap.

So far good luck may have played a favorable role. At any rate Robert P. Patterson, Under Secretary of War, says this fuel has not been lacking for combat purposes, although not sufficient for some training duties.

Failure of the military to estimate its gasoline demands came to light when there was a discussion between William M. Jeffers and Under Secretary Patterson with butadiene units and aviation-gasoline units held up as vieing for prominence. Harold L. Ickes told Congressional committees that he never had been able to get estimates from the Army and the Navy.

It may be that such estimates are impossible. If so, military authorities should admit the fact. As it is the petroleum industry is preplexed. It could do a better job of supply if requirements were known.

The One and The Other

SOMEHOW it is difficult to comprehend the prospect of both a natural rubber and a synthetic rubber existing at one and the same time. Questions written to PETROLEUM REFINER betray this failure to estimate what is in prospect. The questions make up this composite:

"If natural rubber can be produced for as little as 5 cents a pound, how can synthetic rubber compete at 15 cents a pound?"

One answer to that is the difference in quality of the synthetic product. Because of superior qualities, synthetic rubber already has replaced perhaps 30 percent of the former use for natural rubber. Unless some means can be found for making the natural product immune to oxidation, the synthetic product will serve for the future insulation of all electrical wiring. There are countless instances of this superiority.

Again the synthetic product will gain a place where other materials now serve. Piping for home water and gas systems in the future will be of elastic material rather than metal. Even the wall coverings may well be of rubber with color permanently established. There are so many possible adaptations for rubber with qualities that can be built into the synthetic product that it defies limitation.

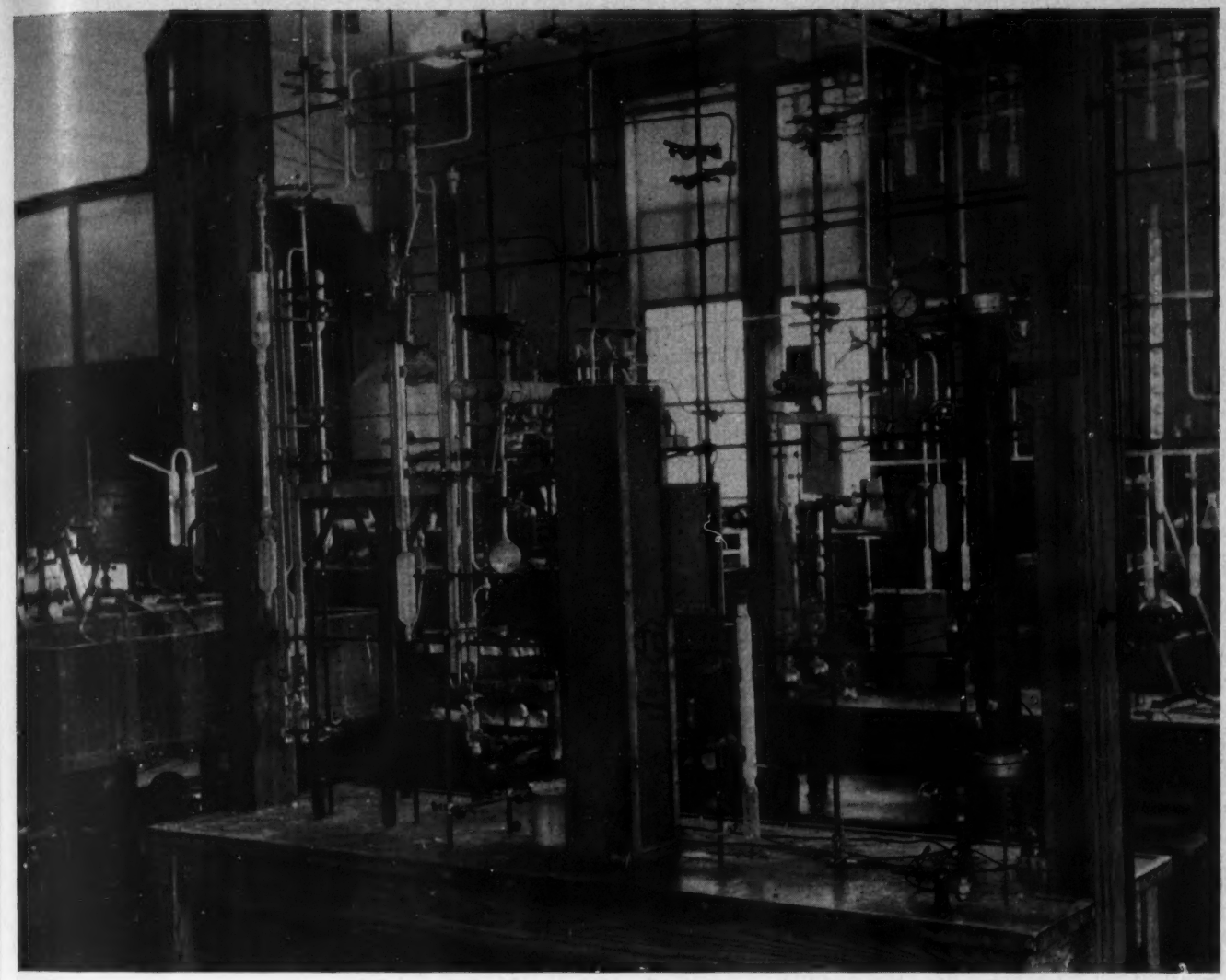
Expansion of rubber use is even more promising. In the United States each person required 10 pounds of rubber per year prior to curtailment of use. In some other countries consumption was as low as a tenth of a pound per person.

Regardless of cost, no one need fear abandonment of synthetic rubber from an economic viewpoint. Only a political demand can bring about this ending. The product simply will be so superior to natural rubber for some purposes that it will be cheaper despite the higher cost.

This is no admission that even cost will continue favorable to the natural product. Before the Chamber of Commerce of the State of New York in June John L. Collyer, president, The B. F. Goodrich Company, called attention to his estimate of three years ago that synthetic rubber could be produced for as little as 25 cents a pound, and that recently William M. Jeffers, Rubber Director, has estimated the cost as low as 16 cents a pound.

Some technologists are convinced that the cost for Buna S rubber finally will be much lower than 16 cents. They base the conviction on what has come about from scientific development in other industries.

What the petroleum industry needs realize is that a synthetic rubber will continue after the war unless stifled for political reasons.



Equipment in the author's laboratory

Hydrogen Fluoride, The Catalyst

J. H. SIMONS
The School of Chemistry and Physics
of The Pennsylvania State College

PART 2. Its Role in Organic Chemical Reactions

IN PART 1 of this paper, (PETROLEUM REFINER, 22, (June, 1943) page 83), the unusual physical and chemical properties of hydrogen fluoride were described. It is seen that these properties are in some instances apparently contradictory. Theoretical consideration of these properties from the point of view of physical chemistry lead to the belief that hydrogen fluoride would be effective for certain purposes in organic chemistry. Minor preliminary laboratory experiments supported this idea. The writer had, however, no facilities for such research, as it required help and facilities in organic chemistry; and he is known as a physical chemist. His fellow workers can probably remember his discussions and his requests for facilities. As these ideas appeared very visionary and as other subjects for investigation were always available, it was not until some years later that a set of fortuitous coincidences supplied facilities in organic chemistry. The original idea of the utility of fluorides has been confirmed; but due to the dependence on meager college budgets and personal funds, the work has not progressed as rapidly as both the academic

scientist and the industry would have liked. Happily other workers in other laboratories were able to contribute to this field of work and further its progress once interest had been stimulated.

The first publication which disclosed the use of hydrogen fluoride as the catalyst for an organic chemical condensation reaction was a note[1] published early in 1938, in the Journal of the American Chemical Society. Subsequent laboratory work soon showed superiority of this catalyst for a large number of reactions and its possibilities for use on an industrial scale. The author was asked to present this subject for the Unit Process Symposium at the September, 1939, meeting of the American Chemical Society. The paper entitled Potential Use of Hydrogen Fluoride in Organic Chemical Processes[2] was subsequently published in February, 1940. The summary of this paper is now interesting to read in retrospect.

"Hydrogen fluoride promises to be of extensive use in organic chemical processes. Fortunately it can be made available in large quantities. Present indications are that it will displace other condensing agents in reactions for which they are used and will also enable new reactions to be carried out not possible with the other agents. Higher yields are to be expected both because obnoxious by-products such as tarry residues and sulfonated sludges are not formed and because the starting materials not used can be recovered. Its physical properties should result in more efficient processing, and greater ease and less cost in the design and use of equipment. It should be recoverable from reaction vessels for subsequent use. Equipment can be made of common materials of engineering construction. In the near future it probably will become one of our more widely used industrial chemicals."

In a series of papers in the Journal of the American Chemical Society the author has published the work from his laboratory on the general subject of Hydrogen Fluoride as a Condensing Agent.[3] Sixteen papers have been published and others are in preparation. No complete bibliography of this subject will be attempted here as this is satisfactorily accomplished elsewhere.

The catalytic power of hydrogen fluoride must be related to its chemical and physical properties. Those that probably govern its action in organic chemical reactions are its solvent power, its high dielectric constant, its high acidity, its great dehydrating tendency, the insolubility of the other halogen halides in it, and its great tendency to combine with itself and other substances to form molecular complexes.

The corrosive effect of hydrogen fluoride on materials of organic chemical composition such as wood, paper, rubber, etc., has been known and appreciated from the time the anhydrous material was first prepared. Its corrosive effect on human tissue and on glass and all silicious minerals was also known. These things lead to the common misconception that hydrogen fluoride would corrode and destroy all organic chemical substances, and that it could not be handled in the laboratory. These misconceptions were in part the reason that facilities to study these actions were so difficult to obtain. It did not seem reasonable that such a corrosive agent could be put to useful service. An analysis of the corrosive action shows the following: The effect on silicious materials is due to the formation of the gaseous silicon tetrafluoride, which escapes the site of the reaction and thus allows it to proceed. The effect on things like wood and paper is primarily a dehydration, for hydrogen fluoride is a powerful drying agent. On rubber and many unsaturated organic chemical substances the effect is due to the powerful polymerizing action of hydrogen fluoride. The effect on human tissue is due to the fact that this very acidic substance is readily absorbed, and both the hydrogen ions and the fluoride ions are toxic.

The polymerizing power of hydrogen fluoride was recognized long ago. Everyone who has worked with the anhydrous material knows how it hardens rubber, either crude or vulcanized, to a hard brittle mass. Unsaturated organic chemical compounds are readily polymerized, particularly those containing the olefin linkage. Fredenhagen[4] lists the following substances as being polymerized by it: oleic acid, linseed oil, poppyseed oil, castor oil, sunflower oil, soybean oil, amylene, butadiene, dipentene, indene, isoprene, piperylene, pyrrole, thiophene, and thionaphthene. Grosse and Linn[5] also include ethylene, propylene and cyclohexene. In our laboratories we have found additional substances to be polymerized such as acetaldehyde, furfural, and acetone. Hydrogen fluoride does not polymerize aromatic hydrocarbons such as benzene, toluene, naphthalene, etc.

In view of the powerful polymerizing power of hydrogen fluoride it is very surprising that it can be used as a catalyst for organic chemical reactions to prepare desired products in very good yields and without the formation of any appreciable amount of unwanted polymers. As soon as it was demonstrated that this was possible and conditions for doing it were found and described, the way for laboratory experimentation on organic chemical reactions was opened. The advantages of hydrogen fluoride over other agents for the same or similar purposes from an engineering point of view then attracted the interest of industry.

One of the reactions for which hydrogen fluoride was found to be an effective catalyst is the one known as alkylation. This is essentially the preparation of a product that contains one or more alkyl or paraffinic groups in its molecules than were in the molecules of the source material. It was found that a great variety of source materials could be alkylated and also that a great variety of materials to supply the alkyl groups could be used. Among the latter are alkyl halides, olefins, alcohols, esters, ethers, etc.

As an example of an alkylation using an alkyl halide we can take the reaction between benzene and an alkyl chloride, butyl chloride. If this is a tertiary chloride, the reaction takes place readily at ice temperature. If it is secondary, the reaction will take place at room temperature; but if it is primary, a temperature of about the boiling point of water or above is necessary to have the reaction proceed readily. In this reaction the hydrogen chloride escapes as a gas, and only a relatively small amount of hydrogen fluoride is necessary for the reaction. It is neither consumed nor diluted except by water or other impurities contained in the raw materials.

As an example of an alkylation using an olefin we can take the reaction of butylene or propylene with benzene. In this case the reaction takes place readily at relatively low temperatures. As the olefins polymerize readily, they are added with stirring to the substance to be alkylated. As the alkylation proceeds much more rapidly than the polymerization, the latter can be almost completely prevented. In this case as

in many kinds of alkylation, polyalkylation can be reduced to a small amount by proper adjustment of rate of addition of olefin and also the relative quantities of alkylating substance and material to be alkylated. If polyalkylation is desired, it can be achieved by proper adjustment of conditions.

As an example of an alkylation using alcohols we can take the reaction of the butyl alcohols with benzene. The tertiary alcohol reacts the most readily, and the primary the least. For two reasons much more hydrogen fluoride is needed in reactions using alcohols as the alkylating substance than when alkyl halides or olefins are used. As water is a product of the reaction, this dilutes the hydrogen fluoride. Alcohols themselves, as well as all organic chemical compounds containing oxygen, have a strong tendency to add hydrogen fluoride and thus reduce its catalytic activity.

As an example of the use of an ester as the alkylating substance we can take propyl acetate. This will react in a similar manner to propyl alcohol except that, instead of water, acetic acid is produced in the reaction.

As an example of the use of an ether for alkylation we can take the reaction of dipropyl ether with benzene. Propyl benzenes are formed as the products. Two reactions are possible, one of the hydrocarbon groups of the ether can react, leaving an alcohol as a product, or both of the hydrocarbon groups can react, leaving water as the product.

The case of alkylation of a certain substance depends not only on the type of alkyl compound but also on the particular alkyl group. For example, propylene reacts more readily than ethylene; and methyl compounds with hydrogen fluoride as the catalyst do not alkylate readily. It is interesting that under a set of conditions in which it was found that methyl alcohol does not react with benzene, it was found to react with phenol; but the methyl group replaces the hydrogen atom of the hydroxyl group rather than a hydrogen atom of the ring. With ethyl alcohol and phenol the ethyl group goes to the ring.

Let us assume that we desire to make ethyl benzene using hydrogen fluoride as the catalyst. We may choose such common substances as ethyl alcohol, ethylene, ethyl chloride, ethyl ether, ethyl acetate, etc., to furnish the ethyl group. A special purified grade of benzene is not required, as hydrogen fluoride is not deactivated by common impurities in it. This is not true for some other catalysts, especially the solid-phase ones. The catalyst is readily recovered, which is also not true of most other agents. The equipment is relatively simple. It is smaller in size for equivalent production than that needed when most other catalysts are used, and it is made of the more readily available materials. The yield of product is very high, and the loss of benzene in side reactions is reduced to a minimum.

Benzene is, of course, not the only substance that can be alkylated using hydrogen fluoride as the catalyst. Any substance that contains, in its molecules, atoms of hydrogen that are sufficiently active for replacement reactions will undergo a similar condensation reaction. Phenol, naphthalene and other aromatic compounds are given as examples. The ease of alkylation is, of course, different with different substances. Phenol, for example, alkylates more readily than benzene. It is, however, not necessary that the substance be aromatic. Paraffinic substances with a sufficiently active hydrogen atom, such as the "so-called" isoparaffins, can also be alkylated. This was demonstrated in our laboratory long ago; but due to the fact that paraffinic compounds are more difficult to identify than aromatic ones and as we did not have good facilities for such identifications and were using student help, we did not report such experiments in our papers in the chemical literature. Others with better facilities for this kind of work were able to make more rapid progress than we could with this phase of the subject.

Hydrogen fluoride is also an effective catalyst for the reaction known as acylation, that is, the condensation reaction which produces ketones as the product. When hydrogen fluoride is used, the two substances caused to react are an organic compound containing an active hydrogen atom in the molecule, such as benzene or toluene, and a carboxylic acid or related compound such as an acid halide, an acid anhydride or an ester. When a carboxylic acid such as acetic acid is used, water is a product. When an acid halide such as acetyl chloride is used, there is an immediate reaction which proceeds the acylation reaction and which produces acetyl fluoride and hydrogen chloride. The hydrogen chloride is a gas which escapes and the acetyl fluoride then reacts to form the methyl ketone and regenerate hydrogen fluoride. An acid anhydride will react with hydrogen fluoride alone to form the acid fluoride and the carboxylic acid. Acetic anhydride, for example, forms acetyl fluoride and acetic acid. As both of these products are useful for acylation, the reaction can be accomplished. It was previously noted that esters act as alkylating substances and that the carboxylic acid is one of the products. The acid is then available for acylation. As the acylation usually requires higher temperature and more hydrogen fluoride than alkylation, ethyl acetate can be used with benzene to form either ethylbenzene, a mixture of ethylbenzene and acetophenone, or also paraethylacetophenone.

Whether the reaction be alkylation or acylation the second group entering the benzene nucleus goes chiefly into the para position. If polyalkylation is desired and the reaction is continued after the second alkyl group has been introduced, then other positions will be occupied. We have reported a tetrapropylbenzene. It is of interest to note that isopropylbenzene is formed from either primary or secondary propyl chloride or alcohol. However, normal propylbenzene is formed when cyclopropane is used.

Hydrogen fluoride can be used as the catalyst for certain other reactions which are related to alkylation and acylation. Examples of these are ring closures and rearrangements. An example of the latter is the Fries change. A similar type of reaction is a variation of an exchange reaction. Examples of these as catalyzed by hydrogen fluoride are: tertiarybutylbenzene reacts with phenol to form benzene and paratertiarybutylphenol, benzophenone oxime rearranges to benzanilide, phenyl acetate rearranges to parahydroxyacetophenone, paracresylbenzenesulfonate rearranges to 2-hydroxy-4-methyldiphenylsulfone.

Hydrogen fluoride is also a useful catalyst for reactions not directly related to alkylation and acylation. For example, it is very effective in aiding sulfonation. Benzene reacts with sulfuric acid in the presence of hydrogen fluoride to form benzene sulfonic acid. At higher temperature diphenyl sulfone

is formed. Mixed sulfones can be formed by treating a sulfonic acid with another organic compound in the presence of hydrogen fluoride. An example of this is the treatment of toluene with benzene sulfonic acid to form the mixed sulfone, paratolylphenylsulfone.

Hydrogen fluoride also catalyzes nitration. Nitric acid reacts with benzene at sub zero temperatures to form mononitrobenzene. Further nitration is not accomplished at the low temperature. Benzene is here used as an example of a reactant. Other substances can be sulfonated and nitrated, using hydrogen fluoride as the catalyst.

Hydrogen fluoride is also an effective catalyst in the formation of esters. Esters of acetic and butyric acids have been made by the reaction of these acids with olefins, using hydrogen fluoride as the catalyst. Ethyl acetate was also made by the reaction of acetic acid and ethyl alcohol. The reverse reaction, that is, the reaction of water with ethyl acetate to form ethyl alcohol and acetic acid is also catalyzed by hydrogen fluoride.

Hydrogen fluoride can also be used as the catalyst in the formation of ethers. Two alcohol molecules can be caused to combine to form the ether and water. In the presence of hydrogen fluoride methyl alcohol and phenol react to form anisole and water. An alcohol can be caused to react with an olefin to form the ether. An example of this is the formation of dicyclohexyl ether by a reaction of cyclohexanol with cyclohexene in the presence of hydrogen fluoride.

Another interesting reaction that has been found to be catalyzed by hydrogen fluoride is the reaction of carbon monoxide with aliphatic compounds to produce carboxylic acids. Both alkyl halides and alcohols have been used. An example of this is the formation of isobutyric acid from ether isopropyl chloride or normal propyl alcohol.

A large number of other reactions of organic chemical compounds have been shown to be beneficially catalyzed by hydrogen fluoride. Many of these are relatively complex and require more detailed technical elaboration than is possible here. The above examples, however, should be ample to demonstrate the wide catalytic powers of this substance. In general it is found that where this catalyst can be used, the yields are better, products contain less obnoxious by-products, operation is accomplished with greater ease and flexibility, equipment design is more satisfactory and production is accomplished in a better and more economical manner.

A consideration of the catalytic powers of hydrogen fluoride show that it has certain similarities with other catalytic substances in some reactions, but that on the whole it is a unique substance with distinct properties of its own. In regard to the catalysis of organic chemical condensation reactions it shows certain similarities to other acidic condensing agents such as sulfuric and phosphoric acid, that is, in some cases the same products are produced. It also has catalytic properties related to aluminum chloride, boron trifluoride, and other metallic halide condensing agents. It seems to be able to catalyze most of the reactions for which these other substances are used. Just why this is true is an important subject for future investigation.

The differences between the use of hydrogen fluoride and other condensing agents are of both theoretical interest and value in commercial practice. Where either hydrogen fluoride and sulfuric acid can be used, there are advantages for the use of hydrogen fluoride in addition to its greater desirability from an engineering point of view. Sulfuric acid has a great tendency to sulfonate organic chemical substances and undesired sulfonated residues are formed. In spite of the fact that hydrogen fluoride can add to organic chemical substances, it cannot react in a manner similar to the formation of these sulfonated products, because it contains no oxygen atoms in its molecules. Sulfuric acid is an oxydizing agent, and the oxidation of the organic chemical substances reduces the yield of desired products and produces obnoxious residues. Hydrogen fluoride is not an oxidizing agent. In most condensation reactions little or no organic fluorides are produced, when hydrogen fluoride is used. There are a number of differences in catalytic action between sulfuric acid and hydrogen fluoride. For example, sulfuric acid is not particularly useful for alkylations employing alkyl halides, whereas hydrogen fluoride is.

When comparing hydrogen fluoride and aluminum chloride, it is difficult to find a similarity of molecular structure to account for any similarities of the products formed in the reactions catalyzed by these substances. Boron trifluoride and aluminum chloride can be considered similar in molecular structure at least in the monomeric form. Each molecule has a central trivalent atom surrounded by three halogen atoms. This gives a valence shell of six electrons and, on the basis of certain theories of structure, a tendency to attract and hold the valence electrons of other substances. In certain theoretical considerations of the catalytic powers of aluminum chloride and also boron fluoride this structure and tendency has been held responsible for the catalytic properties. The structure of hydrogen fluoride is vastly different. In use also hydrogen fluoride acts quite differently than aluminum chloride. The latter shows a great tendency to form tarry residues with all organic chemical substances including aromatic compounds. Hydrogen fluoride shows very little tendency to polymerize aromatic compounds to tars. Aluminum chloride has a great tendency to cause rearrangement of paraffinic compounds. Hydrogen fluoride has much less tendency in this direction. Aluminum chloride when used for alkylation is employed chiefly with alkyl halides and not with alcohols. Hydrogen fluoride can be used with either, but reaction is apparently more rapid with alcohols. In acylation, aluminum chloride is used chiefly with acid halides. Hydrogen fluoride can be used with either the acid halide or the free acid itself. The action with the cheaper and more readily available carboxylic acid seems to proceed more rapidly. There are a number of reactions between organic chemical compounds in which different products are obtained when hydrogen fluoride is used than when aluminum chloride is used. The number of these will increase as the use of hydrogen fluoride is more fully studied. The syntheses catalyzed by hydrogen fluoride should not be classed as Friedel and Craft reactions. This name is restricted to condensations catalyzed by aluminum chloride, boron fluoride, or other metallic halide. The hydrogen fluoride condensations not only proceed differently but in many cases give different products.

The detailed mechanism of the catalytic action of hydrogen fluoride is quite unknown. The particular way that it causes condensation reactions to take place is a subject of very considerable interest.

Studies of this would produce valuable knowledge. Such studies would probably be made in the college laboratory as they would produce no patentable processes. The values obtained from these studies would be very important and useful for industry as a whole, and financial support for the academic work from industry would be very advantageous.

Every easily arrived at mechanism of reaction with some well known substance as an intermediate must be discarded when the properties of the products of the hydrogen fluoride catalyzed condensation reactions are taken into consideration. If it is argued that a double-bonded or olefinic compound is a necessary intermediate, it can be pointed out that benzyl chloride is an effective reagent; and it cannot form an olefin. Although methyl alcohol does not methylate readily, it does condense with phenol to form anesole, and neither methyl alcohol nor phenol can form an olefin. Propylene on reaction with benzene gives isopropylbenzene, but cyclopropane gives normal propylbenzene. If the olefin were the intermediate, the iso compound would be formed. If it is argued that the fluoride is the necessary intermediate, it can be pointed out that normal propyl fluoride on reaction with benzene gives isopropylbenzene; and the normal compound would be expected on this hypothesis. It has also been shown that the fluorides in the absence of free hydrogen fluoride do not react readily. Actually olefins will react much more readily with a much smaller amount of total fluorides present.

For the condensation reactions which take place at low temperature in a hydrocarbon solution the assumption of either free ions or free radicals gives very serious difficulties in regard to energies of activation and must be considered as highly improbable. Such an assumption also leads to other serious inconsistencies. A beginning of a study of the mechanism of one of these reactions has recently been published by Sprauer and Simons.[6] A tentative mechanism is here postulated which, at least, has avoided the above difficulties.

A kinetic study was made of the reaction of toluene and tertiary butyl chloride as catalyzed by hydrogen fluoride. The products are paratertiarybutsyltoluene and hydrogen chloride in nearly 100-percent yield under most conditions. The reaction was shown to be approximately quantitative to one product and to be homogeneous in the hydrocarbon solution. Interesting features were that the reaction was retarded by hydrogen chloride and promoted by water and methyl alcohol. (Friedel and Craft reactions are usually considered promoted by hydrogen chloride.) The mechanism postulated was the transfer through a reacting pair of molecules (toluene and tertiarybutyl chloride) of a hydrogen ion from hydrogen fluoride on one side to a basic substance on the other. As this mechanism does not require the assumption of free ions or radicals, it is more reasonable from an energy point of view. It satisfactorily explains the production of the known products and also furnishes differential equations which correlate the quantitative rate data. Work of this kind is both difficult and time consuming, but it is productive and much more of it is needed.

The industrial use of hydrogen fluoride as a catalyst for organic chemical reactions is just beginning. It has already found some important applications, some of which are at present in large scale practice. As more laboratory work is done and more theoretical considerations are given to the subject, more and more applications will be found. The fundamental work will be done chiefly in the college laboratories in the future as in the past. So far this has not had the benefit of any financial support from any industrial source or federal agency. Such support would greatly accelerate the progress.

For much of the subject matter which is used or referred to in this discussion, I wish to express my thanks and appreciation to the students in our college laboratories whose long hours, day and night, produced much of it. Their work, without financial compensation, using difficult techniques and materials not always agreeable, has produced knowledge of considerable value. The students that have been associated with me have been uniformly hard working and courageous. We must acknowledge the patient work of all those workers and their helpers, chiefly in college laboratories, whose long hours (overtime without pay) have produced the valuable scientific ideas and knowledge. The producers of anhydrous hydrogen fluoride, the users of this material in industrial practice, and the firms which develop processes or design and construct equipment for processes using hydrogen fluoride are benefiting now from this work done in the past and will benefit from any further fundamental work. Encouragement and support for the work from these industries would be both welcome and appreciated.

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A Chart for Determining the Area of Reinforcing Steel Required in Concrete Floor Slabs

The design of reinforced concrete floor slabs may be greatly facilitated by using the nomographic chart shown here. This chart is based on the formula,

$$A_s = \frac{WL^2}{3C}$$

A_s = area of steel in square inches per foot of slab.

W = uniform load on the slab in pounds per square foot.

L = span of slab, as shown in the sketch.

C = a constant, depending upon the kind of concrete and the position of the slab. A slab adjoining a wall or an opening is called an end slab. Otherwise, it is called a center slab. Values used for C are as follows:

Stone Concrete:
Center Spans ..... C = 23 000
End Spans ..... C = 15 000

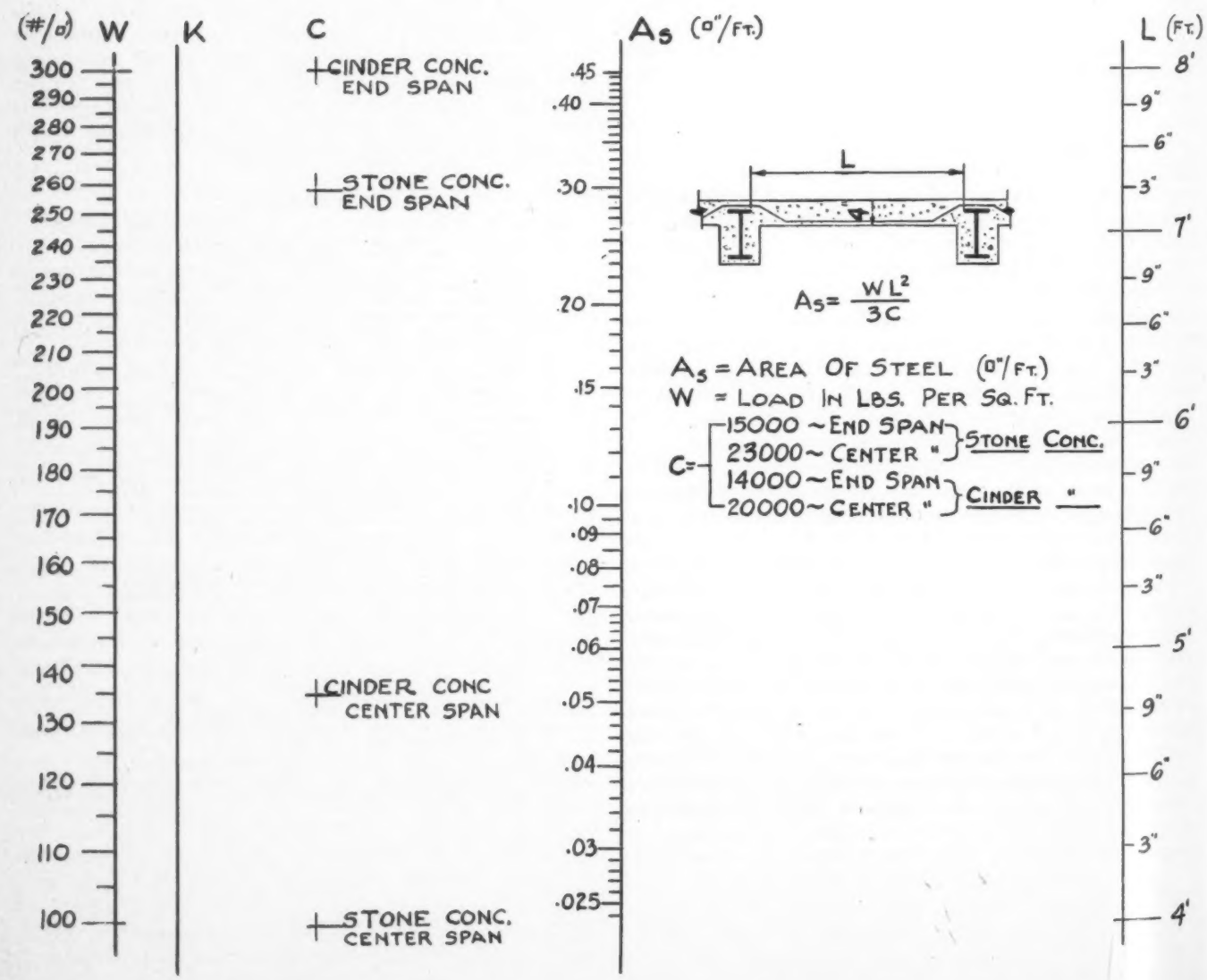
Cinder Concrete:
Center Spans ..... C = 20 000
End Spans ..... C = 14 000

This chart has been a great timesaver in floor slab design for power plants and industrial buildings.

To illustrate the use of the nomographic chart, let us find the area of steel required for an end span, stone concrete slab whose length is 7 feet 3 inches, and which carries a load of 225 pounds per square foot. The procedure is as follows:

1. Draw a line from the C value marked "stone concrete, end span" to the 225 mark on the W line.
2. From the point of intersection of the above with the K line, draw a line to 7 feet 3 inches on the L line.
3. The value of A_s may now be read as approximately .26 square inch.

The proper size of reinforcing steel may now be chosen from tables prepared for this purpose, and available from any steel company.



An Empirical Relation Between Octane Number and Molecular Structure

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IT HAS been repeatedly attempted to deduce a connection between the physical properties of hydrocarbons and their tendency to knock in the engine as characterized by their octane number.

Thus qualitative relationships between structure and octane number have been pointed out by Lovell, Campbell and Boyd[1, 2] and by Lovell and Campbell.[3] Recently Francis[4] has presented quantitative relationships between octane numbers and certain physical properties of paraffins in which each series of isomers is characterized by a different constant.

Lovell and Campbell[3] come to the following conclusions:

1. For the normal paraffin hydrocarbons there appears to be a regular increase in tendency to knock with increase in the length of the chain, or with the molecular weight. This increase in tendency to knock with an increase in the length of the unbranched chain appears to be a quite general relationship. Also, the lengthening of the unbranched chain, when this chain is in the interior of the molecule produces a similar effect.

2. The successive addition of methyl groups to a carbon-atom chain results in a decreased tendency to knock.

3. In general, for a given molecular size, what is loosely termed the centralization of the molecule, is increased, there is less tendency to knock. It is difficult to define this concept of centralization of a molecule quantitatively, but it may be described in a general way as a more compact arrangement of the structural formula of the molecule.

The object of the present paper is to express the centralization quantitatively by a "centralization index" and to show that in fact there is a very simple relationship between this index and the octane number.

The centralization index can be calculated for any paraffin in the following way:

The carbon atoms in the longest straight chain in the molecule are numbered, beginning at each end of the chain.

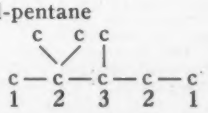
The "centralization index" consists of the sum of these "position numbers" minus a certain value for every side chain, depending on its length and position in the molecule. These values are:

For a methyl group: the position number of the corresponding carbon atom in the straight chain.

For an ethyl group: one unit less than for a methyl group in the same position,

Example:

2, 2, 3-trimethyl-pentane



Sum of position numbers = 9. Value to be deducted for side chains 2 + 2 + 3 = 7

Hence, centralization index: 9 — 7 = 2

The centralization index thus depends only on the molecular weight, chain length and branching of the hydrocarbon and not on its physical properties.

For a given paraffin the octane number will decrease with increasing centralization index and the isomer with the lowest centralization index will have the highest octane number. This is shown in the ex-

TABLE 1

	Research Blending Octane Number	Centraliz. Index
n-Heptane	0	15
2-Methylhexane	55	10
3-Methylhexane	65	9
3-Ethylpentane	68	7
2-2-Dimethylpentane	80	5
2-4-Dimethylpentane	80	5
2-3-Dimethylpentane	94	4
3-3-Dimethylpentane	98	3

TABLE 2

Paraffins

	OCTANE NUMBERS					
	A. S. T. M.		Research			
	Pure	Blending	Pure	Blending	Central Index	O. N. Calculated
Methane	100	.....	>100	.....	1	115
Ethane	104	.....	>100	.....	2	108
Propane	100	.....	>100	.....	4	92
n-Butane	92	.....	95	95	6	77
i-Butane	99	.....	>100	.....	2	108
n-Pentane	61	.....	58	60	9	54
2-Methylbutane	89	81	91	92	4	92
2-Dimethylpropane	83	.....	.....	116	0	123
n-Hexane	25	.....	34	29	12	31
2-Methylpentane	73	.....	.....	69	7	69
3-Methylpentane	75	.....	.....	84	6	77
2, 2-Dimethylbutane	96	.....	.....	.....	2	108
2, 3-Dimethylbutane	95	.....	.....	124	2	108
n-Neptane	0	0	0	0	16	0
2-Methylhexane	45	.....	.....	55	10	45
3-Methylhexane	.....	.....	.....	65	9	54
3-Ethylpentane	.....	.....	62	68	7	69
2, 2-Dimethylpentane	93	.....	.....	80	5	85
2, 3-Dimethylpentane	89	.....	88.5	94	4	92
2, 4-Dimethylpentane	82	.....	.....	80	5	85
3, 3-Dimethylpentane	84	.....	.....	98	3	100
2, 2, 3-Trimethylbutane	101	.....	.....	116	0	123
n-Octane	—17	.....	.....	—19	20	—31
2-Methylheptane	.....	.....	.....	.....	14	15
3-Methylheptane	35	.....	.....	.....	13	23
4-Methylheptane	.....	.....	.....	.....	12	31
2, 3-Dimethylhexane	76	.....	.....	.....	7	69
2, 5-Dimethylhexane	52	.....	.....	69	8	615
3, 4-Dimethylhexane	85	.....	.....	.....	6	77
3-Methyl-3-Ethylpentane	91	.....	.....	.....	4	92
2, 2, 3-Trimethylpentane	102	.....	.....	105	2	108
2, 2, 4-Trimethylpentane	100	100	100	100	3	100
2, 3, 3-Trimethylpentane	.....	.....	.....	.....	1	115
2, 3, 4-Trimethylpentane	97	.....	.....	.....	2	108
2, 2, 3, 3-Tetramethylbutane	103	.....	.....	130	2	138
n-Nonane	—45	.....	.....	—34	25	—69
2, 6-Dimethylheptane	.....	.....	.....	36	12	31
n-Decane	.....	.....	—53	—32	30	—108
2-Methylnonane	93	.....	.....	.....	23	—54
2, 7-Dimethyloctane	.....	.....	34	25	16	0
2, 2, 6-Trimethylheptane	94.8	.....	.....	.....	10	46
3, 4-Diethylhexane	.....	.....	62	55	8	615
3, 3, 4, 4-Tetramethylhexane	.....	.....	.....	124	0	123

ample of the heptane isomers in Table 1. The octane numbers used in this and other tables are taken from Gruse and Stevens.[5]

The octane numbers of all paraffins can be calculated from the centralization index by assuming a linear relationship between centralization index (C.I.) and octane number (O.N.) which gives zero as the octane number for n-heptane (C.I. = 16) and 100 as the octane number for 2,2,4-trimethyl pentane (C.I. = 3). This relationship is

$$O.N. = 123.1 - 7.7 \times C.I. \quad (1)$$

The octane numbers calculated according to this formula are listed in Table 2 and compared with the experimentally determined octane numbers according to various test methods. It will be seen that the calculated octane numbers not only represent sufficiently well the differences in the knocking tendency of the isomers of one paraffin but come close to the experimental values, a very few cases excepted. The exceptions are as follows: The calculated octane numbers for n-octane, n-nonane and n-decane are definitely lower than the experimental values. This might very well be due to the fact that for high values of the centralization index the simple linear relationship (1) does not hold and in fact the relationship between octane number and centralization index is better represented by quadratic equation of the type

$$O.N. = a - b\,(C.I.). + c\,(C.I.)^2 \quad (2)$$

where a, b and c are constants. For example an equation

$$O.N. = 131.6 - 11\,(C.I.) + 0.179\,(C.I.)^2 \quad (3)$$

will give the following values:

	C.I.	O.N.
2,2,4-Trimethylpentane	3	100.2
n-Heptane	16	1.4
n-Decane	30	—37

At the moment, the octane numbers of sufficiently many paraffins having high centralization indices are not known to warrant the replacement of the simplified equation (1) by a quadratic one.

The experimental octane number of 2-methylnonane (93) is far higher than one would expect from the value of centralization index which is 23. This figure would indicate that the octane number of 2-methylnonane should be between that of n-nonane and n-octane, as these latter hydrocarbons have the centralization indices 20 and 25, respectively. Thus the octane number of 2-methylnonane should be around —30. Also in the case of 2,2,6-trimethylheptane the reported octane number (94.8) is higher than the one that would follow from a centralization index of 10. The same is the case for 2,7-dimethyloctane.

The presented empirical relation between octane number and structural formula will be found useful in the following instances.

1. It permits the classification of the isomers of a given paraffin according to their octane number on the basis of their structure.

2. It permits the approximate estimation of the octane number of any paraffin hydrocarbon either by direct calculation or by comparing it to other hydrocarbons having similar centralization indices.

3. It may serve as a mnemonic aid for remembering the approximate octane number of the various hydrocarbons.

4. It may help in pointing out octane number determinations which are not sufficiently accurate.

The developed relation cannot be extended directly to olefins. A relationship has been found for the octane number of straight-chain mono-olefins.

In the case of straight-chain mono-olefines, the centralization index is calculated in the following manner:

The carbon atoms are numbered, beginning at each end of the molecule. The centralization index consists of the sum of these position numbers, minus a certain value for the double bond, depending on its position. This value is equal to two and a half times the position number of the outer carbon atom plus the position number of the inner carbon atom of the double bond.

Example:

pentene — 2

$$\begin{matrix} C & - & C & = & C & - & C & - & C \\ 1 & & 2 & & 3 & & 2 & & 1 \end{matrix}$$

Sum of the position number = 9.
Value to be deducted four double bond = $2\frac{1}{2} \times 2 + 3 = 8$
Hence, a centralization index $9 - 8 = 1$.

The centralization indices for straight-chain mono-olefins are listed in Table 3, together with the corresponding experimental octane numbers.

From these centralization indices the octane numbers of straight-chain olefins were calculated according to the empirical formula

$$O.N. = 110 - 5\,(C.I.) \quad (4)$$

and the calculated octane numbers are listed on Table 3 in the last column. Again, a fairly good agreement will be noted between the calculated and experimental octane numbers.

Summary

A relation was found connecting the octane numbers of paraffin and straight-chain mono-olefin hydrocarbons with their molecular structure. The molecular structure is represented by the centralization index, which varies with the length of the chain, the kind and the position of the side chains and the position of the double bond.

The method of calculating the centralization index is given and the relationship between centralization index and octane number for a number of paraffins and straight-chain mono-olefins is demonstrated in tabular form.

TABLE 3

Straight Chain Mono-Olefins

	OCTANE NUMBERS					
	A. S. T. M.		Research			
	Pure	Blending	Pure	Blending	Central Index	O. N. Calculated
Ethylene	81	.....	>100	85.5	—1.5	117
Propene	85	.....	>100	102	—0.5	112
Butene-1	80	.....	.....	111.5	1.5	102
Butene-2	83	.....	.....	.....	—1	105
Pentene-1	.....	.....	92	98.5	4.5	87.5
Pentene-2	80	107	98	125	1	105
Hexene-1	.....	.....	80	85	7.5	72.5
Hexene-2	78	.....	89	100	4	90
Hexene-3	.....	.....	97	.....	1.5	102
Heptene-1	.....	.....	54	55	11.5	52
Heptene-2	.....	.....	70	.....	8	70
Heptene-3	.....	.....	84	95	4.5	87
Octene-1	.....	.....	39	25	15.5	33
Octene-2	55	.....	.....	55	12	50
Octene-3	.....	.....	.....	73	8.5	67
Octene-4	.....	.....	.....	91	6	80
				15	20.5	8

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A Simplified Lubricating Oil Oxidation Stability Test

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IN THE course of research conducted for the general purpose of improving lubricating oils, various types of apparatus have been utilized for obtaining a measurement of the stability of oils toward oxidation and the subsequent deterioration of the oil. The Underwood machine, the Indiana Oxidation equipment, the oxygen absorption apparatus, etc., all have been found useful for certain purposes. Probably the last named of these devices yields the greatest amount of fundamental information on the mechanism of the oxidation reaction and on the variables which affect it. However, for the more or less routine examination of a large number of oil samples, the amount of time and work involved in studying the complete oxidation characteristics of all of the oils by means of the absorption apparatus becomes prohibitive. A simple "sorting" device, therefore, is desirable.

Using the fundamental knowledge that has been obtained through the operation of oxygen absorption units,[1,2] it should be possible to develop a simplified test that would prove to be very useful in any type of research which involves the relative evaluation of a large number of blends. It should be understood, of course, that no laboratory test method can replace full-scale engine tests or field tests under actual service conditions, but it can supplement these tests and, by serving as a "sorting" device, greatly reduce the number of oils which must be so tested.

Obviously, service conditions to which lubricating oils are subjected vary greatly. It is not possible, consequently, to have one test which will correlate with all service conditions or engine-block tests, nor does this seem necessary. However, by the incorporation of sufficient flexibility into the design of the test it should be possible to vary laboratory test conditions so as to insure maximum usefulness. In the development of such a test the following desirable features should be incorporated.

(1) The test should be simple and should not consume excessive time either of the operator or in reaching a result.

(2) The conditions imposed on the oil should resemble the significant factors in engine deterioration. The more important of these conditions are:

(a) *Time and Temperature.* The temperature of oxidation is one of the most important variables, since it is known that the rate of oxidation approximately doubles for each 10° C. (18° F.) increase in temperature. The actual temperature selected for the test will depend upon the severity desired, varying from about 100° C. (212° F.) in mild tests, such as for turbine oils, to about 180° C. (356° F.) for extremely severe tests. It is desirable that the laboratory method should be accelerated to expedite the testing but the time of oxidation should be sufficient to permit the initiation of chain reactions controlling the rate of oil deterioration. Experience has shown that for lubricating oils oxidized in the presence of metals at temperatures ranging from 140° C. (284° F.) to 180° C. (356° F.), 10 to 50 hours will generally be sufficient to pass beyond any induction period the oil may possess. Over narrow limits, time and temperature are practically interchangeable; that is, a prolonged time compensates for a lowered temperature.

(b) *Catalysts.* The major engine metal catalysts are believed to be iron and copper.

(c) *Ventilation and Agitation.* The loss of volatile oxidation products should probably correspond to that which takes place in the engine. This factor undoubtedly varies considerably among engines of different makes and with varying operating conditions. Agitation in the crankcase is vigorous due to splashing and pumping. Duplication and independent variation of these factors in a test procedure which depends upon air-blowing for both is difficult. However, the blowing technique is simple. Work in this laboratory has indicated that no great variations may be anticipated by stirring, spraying, or oxidizing with a greater retention of volatile products. Consequently, the blowing method is favored.

(3) The procedures used for oxidation and analysis must be reproducible and capable of differentiating between stable and non-stable oils.

(4) The apparatus should be flexible so that conditions may be changed to yield correlation with differing operating conditions or to yield different types of information.

With these considerations in mind, a simplified laboratory oxidation test was developed. It should be understood that this test is to be primarily an oxidation-stability test, and that other possible causes or effects of crankcase-oil deterioration, such as carbon formation, high-temperature pyrolysis on pistons, soot and carbon contamination of the oil together with any dispersing effect thereupon, and the effect of blow-by constituents, will be evaluated only incidentally, if at all.

Description of the Apparatus

Briefly, the aparatus consists of a thermostat, oxidation tube, slides for lacquer determination, a suitable air supply, catalysts with devices for the measurement and control of air-flow rate and oil temperature. A detailed description of the essential parts follows:

Thermostat. The test requires a definite oil temperature rather than a definite thermostat temperature, so that any thermostat capable of maintaining the oil undergoing oxidation at the predetermined oxidation temperature to within about 1° F. (0.6° C.) is suitable. The thermostat in use at this laboratory is illustrated in Figures 1 and 2.

It consists of an electrically heated block of cast aluminum containing fourteen wells, 1⅞-inch (4.8

* Present address, Standard Oil Development Company, Elizabeth, New Jersey.

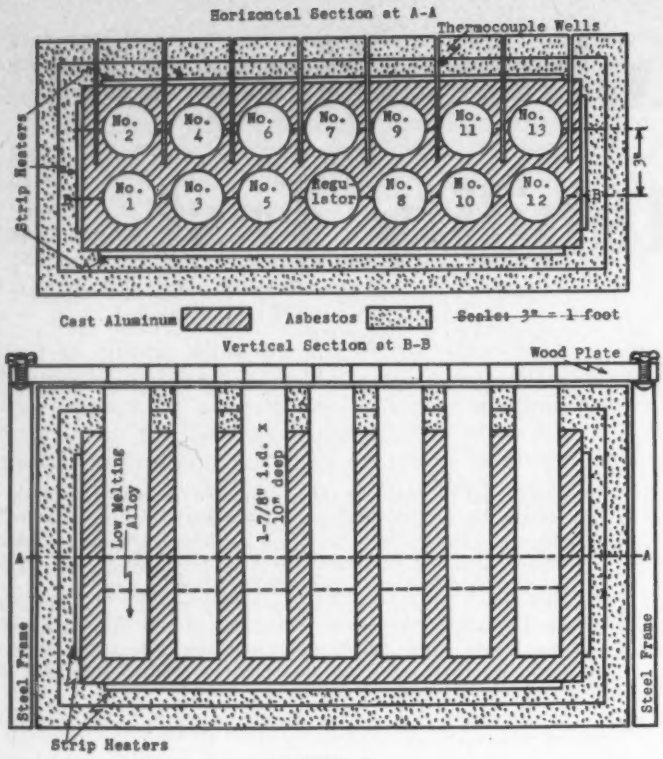

FIGURE 1
Thermostat used in stability test

cm.) inside diameter and 10 inches (25.4 cm.) deep, placed in two parallel rows with 3 inches (7.6 cm.) center to center distance between rows. The wells, which are of steel tubing cast into the block, extend 1 inch (2.54 cm.) above the block surface and are surrounded on all sides and the base by at least 1 inch of aluminum. To insure good thermal contact between the block and the glass oxidation tubes, approximately 2.9 pounds (129 ml.) of lead-bismuth eutectic alloy, melting at about 240° F. (115.6° C.) is placed in each well. The alloy is obtained under the name of "Cerrobase" from the Cerro de Pasco Copper Corporation, New York. Because of the buoyancy of the glass tubes immersed in the molten alloy, it is necessary to force them to the bottom of the well by means of a wood plate suitably bored with large holes for inserting the air-inlet tube, lacquer slides, and thermocouple well. The bi-metallic thermoregulator is also immersed in the molten alloy.

Heat is suppied by means of electric strip heaters clamped to the sides, ends, and base of the block. As shown in section in Figure 1, all surfaces of the block are covered with two 1-inch layers of asbestos.

The strip heaters are arranged in four circuits of two each, with each circuit being equipped with switches and rheostats so that the heat input of any circuit can be adjusted so as best to insure a constant temperature throughout the block. The wiring diagram is presented in Figure 2. A pair of 500-watt heaters clamped to the upper sides of the block are used only for bringing the block up to temperature. With maximum heat to all circuits, 2500 watts are available for this purpose. This is sufficient to carry the block from room temperature to 347° F. (175° C.) in less than 2 hours. Pairs of 250-watt heaters fastened to the ends and base of the block normally supply heat at all times to maintain operating temperature. The current supplied to the pair of 250-watt heaters clamped on the lower sides of the block is controlled by an electronic relay actuated by a bi-metallic thermoregulator inserted into the block in the position between holes 5 and 8 indicated in Figure 1. The electronic relay[8] shown in Figure 2 may be used, or any other suitable one such as that described by Serfass.[3] For operation at an oil temperature of 347° F. (175° C.) the normal switch positions are as follows:

Switch	Heaters	Switch Position at 347° F.	Maximum Wattage At This Setting
A	250-W. End	On	500
B	500-W. Side	Off	0
C	250-W. Side (controlled)	Medium	250
D	250-W. Base	Medium	250

This heat input is then adjusted by means of the rheostats to balance the heat loss from the block which is less than 500 watts when operating at 347° F. The controlled heat should be a small fraction of the total input.

Oxidation Tube. The oxidation tube is a Pyrex test tube 1.5 inches (38 mm.) outside diameter by 12 inches (300 mm.) long. The inside diameter is 1.33 ± 0.04 inch (35.0 ± 1.0 mm.). During oxidation this tube contains the oil, the thermocouple, the air supply tube, the lacquer slides, and the catalysts. The oxidation tube is illustrated in Figure 3, together with the air-inlet tube and glass lacquer slides.

Air Supply and Slides for Lacquer Determination. The air used for oxidation is dried by passing it through a bed of activated alumina before it enters the oil. The rate of air flow is held at 10 liters per hour (± 10 percent), measured at room temperature by means of capillary tube flow-meters. These devices consist of capillary tubes in the air line across which the pressure drop is measured by means of oil-filled manometers. The flow-meters are initially calibrated against a standard wet-gas meter. Air induction into the oil is by means of a glass tube, 0.12 inch

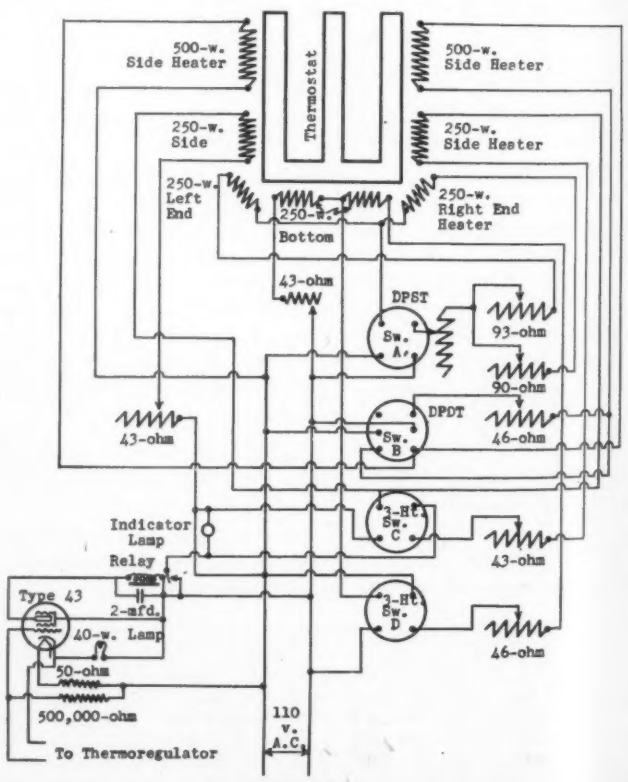

FIGURE 2
Heating circuit for stability-test thermostat

(3.0 mm.) inside diameter and at least 15 inches (360 mm.) long, extended to the bottom of the oxidation tube. Two glass hooks are sealed to the air inlet tubes opposite each other at a point about 3.75 inches (9.5 cm.) from the lower end to support the glass slides used for the lacquer determination. These glass slides are ordinary microscope slides, 1 x 3 inch (2.54 x 7.62 cm.), which are weighed before and after the oxidation in order to obtain a measure of the tendency of the oil to form lacquer. In order to suspend the slides from the hooks provided on the air supply tubes, a 0.25 inch (0.64 cm.) diameter hole is drilled in the glass slides about 0.5 inch (1.27 cm.) from one end.

Catalysts. The catalyst which, under the conditions of test described here, was found to yield results that correlated reasonably well with engine-test data consists of a sheet of commercially pure iron and 15.75 inches (40 cm.) of No. 24 copper wire. The iron catalyst is prepared from a rectangle of Armco Ingot iron 3 x 3.75 inches (7.6 x 9.5 cm.) cut from 22-gauge cold-rolled, oiled sheet. The iron sheet is washed with a light naphtha to remove oil, and is polished successively until bright with Nos. 1 and 00 metallographic emery paper. A cylinder 3 inches (7.62 cm) long is then formed from the sheet by wrapping it around a 1.25-inch (3.18 cm.) mandrel. This leaves a gap ⅛ to ¼ inch wide up one side of the cylinder. The copper wire, prepared by abrading it with No. 00 metallographic emery paper, is then wound into a spiral on the same mandrel, compressed slightly and inserted into the iron cylinder. After again being washed with naphtha, the cylinder is inserted into the oil under test. The iron cylinder fits rather snugly in the glass tube, so that the iron surface acting as a catalyst may be only one half of the total iron surface.

Temperature Measurement. It is essential that the oil temperature be known and maintained accurately in order to secure reproducible results. It is recommended that the oil temperature be maintained constant to ± 1° F. (0.6° C.) throughout the test. If this average temperature is maintained constant and does not differ from the desired test temperature by more than 5° F., it may be possible to correct the over-all oxidation for this variation by shortening or extending the time of oxidation, using the assumption that the oxidation is doubled, or the time required to produce an equivalent amount of oxidation is halved, for each 18° F. (10° C.) rise in temperature. Mathematically, this can be expressed as follows:

$$\theta = \theta_o 2^{\left[\frac{t_o - t}{18}\right]} \quad \text{or} \quad \log \theta = \log \theta_o + 0.0167\ (t_o - t)$$

where θ = actual time in hours required at t° F.
θ_o = base time of oxidation at t_o° F.

The temperatures normally employed for an accelerated oxidation test of this nature range from about 250° to 350° F. (121° to 177° C.) depending on the severity desired. In correlations of the results with the 36-hour Chevrolet-engine-test data, a temperature of 347° F. (175° C.) was found to be suitable.

The use of individual thermocouples provides an accurate and convenient means of measuring the oil temperatures in the different wells. The thermocouple installation in the block described above consists of 13 individual junctions of No. 26 duplex glass-insulated copper-constantan wire, each of which is placed in a well of glass tubing 12 inches (30 cm.) long by 0.12 inch (3 mm.) inside diameter and 0.20 inch (5 mm.) outside diameter. Thermal conduction to the junction is aided by filling the space between it and the glass well with a solid mass of anthracene. The 13 junctions, together with 8 others inserted directly into the block as shown in Figure 1, are connected to a multiple selector switch and junction box. The e.m.f. of the couples is measured with a potentiometer capable of reading to within 0.01 millivolt. This is equivalent to ± 0.3° F.

Time. The duration of the test is normally 20 hours, although this may be varied depending upon the object of the test, as will be described in a later section. No intermediate oil samples are taken.

Test Procedure

The test procedure described here is the one found to yield a reasonable correlation with the 36-hour Chevrolet-engine-test results.[7] This represents moderately severe operating conditions. Modifications of this procedure are desirable for other purposes and these will be discussed in a later section. The oil charge, 100.0 ± 0.5 grams (0.22 lb.) is placed in the oxidation tube together with the sheet-iron and copper-wire catalyst prepared as described above. The tube is then placed in a well in the thermostat, the air-inlet tube with two lacquer slides and the thermocouple are then inserted, and one hour is allowed to bring the oil approximately to the oxidation temperature (347° F. or 175° C.). During this time no air is bubbled through the oil. The end of the hour allowed for warming-up is taken as zero time for the start of the run, and the air rate is then adjusted to 10 liters per hour. The oil temperature is measured and recorded at least once in every eight-hour period. In determining the average oil temperature during the run, values measured before the end of the first hour of oxidation are not used.

At the end of the oxidation period the air inlet tube and lacquer slides are removed and the effect of oxidation is measured in terms of the following five factors:

1. Lacquer formation.
2. Oil-insoluble matter.
3. Oil-soluble, isopentane-insoluble matter.
4. Viscosity increase.
5. Neutralization number.

As a preliminary step in the analysis of the oxidized oil, it is necessary to provide a clarified oil sample, or one which has been substantially freed from oil-insoluble material. This operation is performed by filtration through Corning fine porosity (F) sintered glass filters (suitably those of 30-milliliters' capacity). Filtering is done at least 24 and not more than 72 hours after the oxidation has been completed. Just before clarification the oil is vigorously agitated so that a representative sample, including oil-insoluble material may be filtered. About forty milliliters of clarified oil are required for subsequent tests. This filtered sample will be referred to as the "clarified oil."

Oil Insoluble Matter and Oil-Soluble, Isopentane-Insoluble Matter. The amount of oil-insoluble matter is determined as the difference between the amounts of isopentane-insoluble material obtained from the oxidized oil before and after clarification. The amount of isopentane-insoluble material as determined on a sample of the clarified oil is recorded as the "oil-soluble, isopentane-insoluble matter." That is, a sample of the original oxidized oil is treated with commercial isopentane and the insolubles are measured. In exactly the same way, a sample of the "clarified

oil" is treated with the same precipitant. The content of insolubles and precipitables in both the unclarified and in the clarified oxidized oil is determined as follows:

A sample of 10 grams (± 0.1 gram) of oil (in one case an original oxidized sample, and in the other, the clarified sample) is diluted with 100 ml. of commercial isopentane. The oil-isopentane mixture is allowed to stand over-night in a cool place. Insoluble or precipitated material is removed from the solution by filtration through a previously weighed and dried Gooch crucible (prepared as described below). The precipitate on the filter is then washed with 50 ml. of additional isopentane. After drying about one hour at 300° F. (150° C.) the deposit in the crucible is weighed.

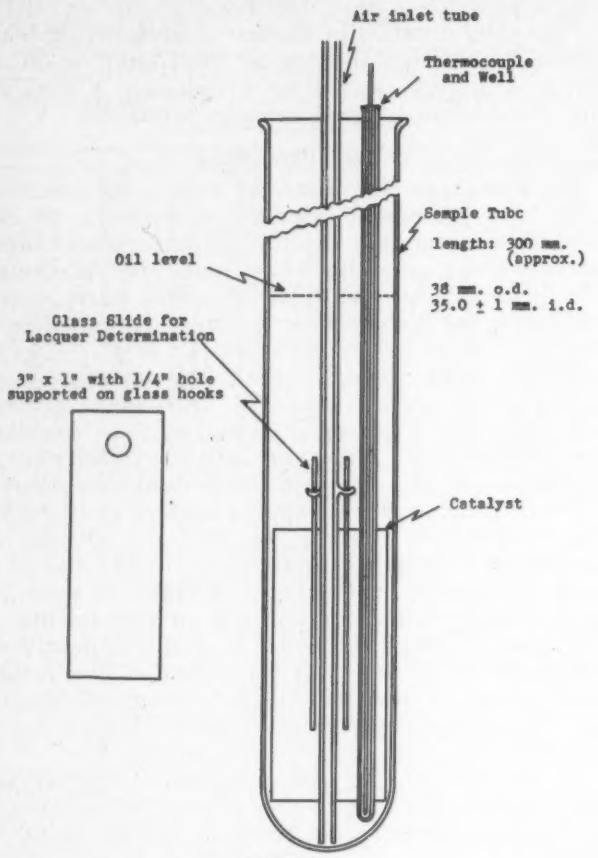

FIGURE 3
Oxidation tube for stability test

The Gooch crucibles are prepared by depositing a thin, uniform mat of 0.2-0.3 grams of medium fibre, acid-washed asbestos over the bottom of the crucible. Using the full suction available from a good water aspirator, the appropriate amount of the asbestos suspension in distilled water is poured quickly into the crucible. The water is sucked through immediately and the asbestos forms a compact layer. The crucible is dried in an oven at 300° F. to constant weight, and should be inspected before use to make sure that the mat covers the crucible bottom completely, with no apertures through which insoluble material could pass. It is intended that a quantitative separation of insoluble material from the solution shall result from this filtration, and the Gooch used for this purpose should be equivalent to one used for any inorganic analytical separation.

The percent of isopentane precipitate from the clarified oil is reported as "oil-soluble, isopentane-insoluble matter."

The amount of "oil-insoluble material" is then calculated as follows:

$$\text{Percent oil insolubles} = A - \left[B \times \frac{100 - A}{100 - B} \right]$$

where A = Percent total isopentane precipitate from unclarified oil.
where B = Percent isopentane precipitate from clarified oil.

For values of A less than 1.00, the percent of oil-insolubles may be taken as simply (A — B).

Of course, any of the numerous methods in use for determining insoluble material may be substituted for the above procedure. The amount of insolubles will depend to some extent upon the method of determination and in certain cases it may be desirable to measure the naphtha insolubles and chloroform solubles as is commonly done in the analysis of used crankcase oils. The present method has the advantage of distinguishing between material insoluble in the oil (which presumably would be the major source of dirtiness in an engine in the absence of extraneous contaminants) and the oil-soluble material which can be precipitated by the addition of a solvent (a potential source of dirtiness in the engine).

Lacquer. The tendency toward lacquer formation is evaluated in terms of the milligrams of deposit acquired by a standard 3 x 1 inch (7.6 x 2.5 cm.) microscope slide immersed in the oil during oxidation. Two slides are used for each oil as shown in Figure 3 and the average gain in weight is reported. Before use, the slides are carefully cleaned, dried in an oven at 220° to 300° F. (105° to 150° C.), and kept in a dessicator until weighed. The slides must be weighed on an analytical balance with an accuracy of ± 0.0001 grams. When the oxidation is completed, the slides are withdrawn, and, after allowing time to drain and cool, are washed with precipitation naphtha (suitably by directing against the slide a jet of liquid from a small washbottle). Any loosely-adhered sludge particles which are not part of the lacquer film may be dusted off gently, using a fine camel's-hair brush. The slides with their lacquer deposit are then dried in an oven at 220° to 300° F. for about 4 hours and again weighed. The average milligrams increase in weight for the two slides are recorded as the slide lacquer deposit.

Viscosity Increase. The viscosity increase is here defined as the percent increase in the kinematic viscosity of the clarified oil at 100° F. (37.78° C.) and is determined using suitable viscosity instruments such as modified Ostwald viscometers (A.S.T.M. D445-42T).

Neutralization Number. The neutralization number is determined on the oxidized oil previous to clarification by titrating the acid in the oil with standard alkali. Since some difficulty was experienced in the use of the A.S.T.M. procedure (D663-42T) with dark, oxidized oils, a method employing a fluorescent indicator was developed. The solutions required and the analytical procedure are described.

Standard Base: A 0.1 normal solution of sodium butylate in n-butyl alcohol is prepared by adding the required amount of sodium to n-butyl alcohol. The exact normality may be found by titrating 10 ml. of the solution in a solvent consisting of 10 ml. of 95-percent ethyl alcohol and 50 ml. of water against an aqueous mineral acid solution of known normality using phenolphthalein indicator. The sodium butylate solution may also be standardized against potassium acid phthalate.

Solvent: This is a mixture of equal parts by volume of normal alcohol and toluene. The butyl alcohol may be distilled from sodium carbonate to ensure absence of acids.

TABLE 1

Average Engine Test Data on S. A. E. Cooperative Test Oils Run by 36-Hour Chevrolet Procedure

Oil Designation	No. of Labs. Reporting	ENGINE CONDITION		ANALYSIS OF USED OILS			
		Percent Engine Demerits	Bearing Loss (Grams per ½ Bearing)	Percent Naphtha Insolubles	Percent Chloroform Solubles	Percent Viscosity Increase, S.U.S. at 100° F.	Neutralization Number
B-1	8–12	20	0.31	1.68	1.22	79	2.0
B-2	8–12	12	1.13	0.76	0.23	97	4.9
B-3	8–12	8	0.27	0.41	0.10	22	1.2
B-4	8–12	52	0.21	3 00	2.77	219	4.5
B-11	5	26	0.24	2.39	2.01	176	1.8
B-12	5	19	1.31	1.15	0.48	115	6.5
B-13	5	8	0.28	0.56	0.16	28	1.0
B-14	5	41	0.04	1.93	1.89	151	4.6
C-1	1–14	10	0.09	0.81	0.13	47	0.5
C-2	1–14	5	1.50	0.68	0.18	253	2.2
C-3	1–13	65	0.17	1.98	1.52	195	0.2
D-6	5	5	0.03	0.52	0.31	44	0.42
D-10	4–5	38	0.17	3.37	2.79	117	2.16
D-14	4–5	47	0.41	6.11	5.76	514	1.57
D-15A	7–10	20	0.08	1.46	1.02	39	0.84

Indicators: (1) *Methyl Red Solution.* This is prepared by dissolving 0.1 percent of methyl red in the butyl alcohol-toluene solvent.

(2) *Fluorescein Solution.* This consists of 0.1 percent of fluorescein dissolved in 95 percent ethyl alcohol. The addition of a few drops of alcoholic potassium hydroxide aids in dissolving the fluorescein.

Before withdrawing a sample, the oxidized oil should be thoroughly shaken to suspend any sludge particles uniformly through the oil. A definite weight of the oil, or a 5 ml. portion or other suitable volume, is withdrawn, using a pipette with a relatively large opening so that sludge particles will not clog the tip (an ordinary 5-ml. pipette can be adapted readily for this purpose by calibrating and using upside down). The contents of the pipette are transferred to an Erlenmeyer flask of 500 ml. capacity and 50 ml. of solvent are added. A portion of the solvent is used to rinse the pipette. About 4 ml. of the methyl red solution, and 2 ml. of fluorescein solution are then added.

The alkali is then added dropwise from a burette (a burette of 10 milliliters capacity, graduated in 0.05 milliliters units, is convenient). On the acid side of the neutral point the presence of the methyl red masks the green fluorescence which develops strongly and quite sharply when the solution becomes alkaline. Observation of the end point is aided by illuminating the titrating vessel strongly from the side, and using a dark background to reduce transmitted light. Bright sunlight, or a No. 1 Photoflood lamp with an opal glass diffusing screen, are suitable light sources. Since different light may affect the operators' evaluation of the end point, it is well to standardize upon one source.

Neutralization number by the A.S.T.M. procedure is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. The same basis may be used for this test. If the oil sample is measured by volume, it is necessary to know or be able to estimate the density of the oil. It will usually be sufficiently accurate to use the density of the oil previous to oxidation, as determined from the A.P.I. gravity.

The volume of alkali used in the titration should be corrected by subtracting from it the amount required to produce a definite fluorencence in a mixture of 50 ml. of solvent, 4 ml. of methyl red, and 2 ml. of fluorescein solutions. This blank value is normally about 0.02 to 0.05 ml. of 0.1N alkali.

The calculation of the neutralization number is performed as follows:

$$\text{Neutralization Number} = \frac{(56) \times (A) \times (N.F.)}{(d) \times (B)} = \frac{(56) \times (A) \times (N.F.)}{(G)}$$

where (A) = Volume of alkali, corrected for blank, in milliliters.
(B) = Volume of oil sample used, ml.
(d) = Density of oil, g./ml.
(N.F.) = Normal factor of alkali.
(G) = Weight of oil sample used, grams.

Correlation with Chevrolet-Engine-Test Results

The stability test described in this report has been devised so as to permit flexibility of operation. The test procedure outlined those conidtions of test which were found to be useful in correlating laboratory results with the data from the 36-hour Chevrolet-engine test.[7] The oils used for this investigation were 15 of the S.A.E. cooperative engine-test oil samples on which engine-test data were available.[4,5,6] The engine-test data reported by the several cooperating laboratories have been averaged and are presented in Table 1. The column headed "Percent Engine Demerits" equals 100 minus the "Engine Deposit Rating" of the original data. This change was made so that increasing values would indicate increasing engine deposits.

These 15 oils were oxidized by means of the stability test procedure outlined above; that is, oxidation for 20 hours at an oil temperature of 347° F. (175° C.) in the presence of a strip of Armco iron 3 x 3.75 inches and 15.75 inches (40 cm.) of No. 24 copper wire, using an air rate of 10 liters per hour. The analytical data obtained as described previously, together with the percent naphtha insolubles and the percent chloroform solubles determined by the procedure used for the crankcase-oil analyses (7, Method A) are presented in Table 2. The correlation between the average engine test data and some of the results given by the laboratory test is presented in Figures 4 and 5. It is noted that a reasonable agreement is obtained for the relative degree of oxidation of the oil, particularly with regard to viscosity increase and insoluble products. The lack of agreement in the neutralization numbers is not surprising in view of the sensitivity of this measurement and the variations normally encountered in engine tests; in some cases the neutralization numbers reported by different laboratories differed by more than 100 percent.

In general, however, the correlation obtained in this work appears to be sufficiently satisfactory to warrant the use of the simplified stability test

TABLE 2

Laboratory Stability Test Results on S.A.E. Cooperative Engine Test Oils

S.A.E. Co-operative Engine Test Oil	Results of Stability Test After 20 Hours at 347° F. Catalyst: Iron Sheet 3 x 3.75 Inches +15.75 Inches No. 24 Copper Wire						
	Milligrams Of Lacquer	Percent Naphtha Insolubles	Percent Chloroform Solubles	Percent Oil-Solubles, Iso-C_5H_{12} Insolubles	Percent Oil Insolubles	Percent Increase in 100° F. Viscosity	Neutralization Number
B-1	0.1	1.11	0.49	0.67	0.38	27.5	1.15
B-2	0.0	0.96	0.53	0.14	0.07	31.1	2.00
B-3	0.0	0.61	0.21	0.22	0.00	17.6	1.25
B-4	1.4	2.53	2.23	1.77	2.10	58.2	2.40
B-11	1.5	1.26	0.51	0.64	0.59	52.6	1.00
B-12	1.1	1.37	0.80	0.52	1.27	45.7	2.60
B-13	0.1	1.66	0.69	0.06	1.23	12.6	1.10
B-14	10.2	4.19	3.56	1.67	3.20	41.1	3.50
C-1	0.2	0.75	0.13	0.49	0.10	17.4	1.20
C-2	0.2	0.46	0.07	0.00	0.90	6.7	0.25
C-3	1.5	1.74	1.24	1.53	1.63	47.0	2.10
D-6	0.0	0.53	0.21	0.03	0.01	23.3	0.25
D-10	1.6	2.51	1.76	1.01	1.57	31.9	1.75
D-14	0.1	4.15	3.66	3.61	1.92	82.9	3.40
D-15A	2.0	1.91	1.52	1.29	1.97	18.6	1.85

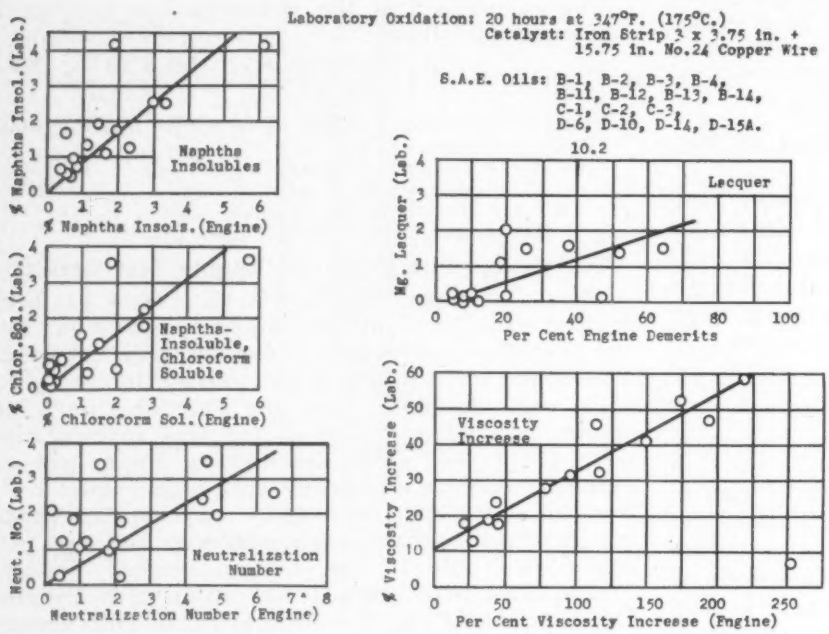
Laboratory Oxidation: 20 hours at 347°F. (175°C.)
Catalyst: Iron Strip 3 x 3.75 in. + 15.75 in. No.24 Copper Wire
S.A.E. Oils: B-1, B-2, B-3, B-4, B-11, B-12, B-13, B-14, C-1, C-2, C-3, D-6, D-10, D-14, D-15A.
% Naphtha Insol.(Lab.)
Naphtha Insolubles
% Naphtha Insols.(Engine)
% Chlor.Sol.(Lab.)
Naphtha-Insoluble, Chloroform Soluble
% Chloroform Sol.(Engine)
Neut. No.(Lab.)
Neutralization Number
Neutralization Number (Engine)
10.2
Mg. Lacquer (Lab.)
Lacquer
Per Cent Engine Demerits
% Viscosity Increase (Lab.)
Viscosity Increase
Per Cent Viscosity Increase (Engine)

FIGURE 4

Correlation of laboratory and Chevrolet-engine test data on S.A.E. cooperative test oils

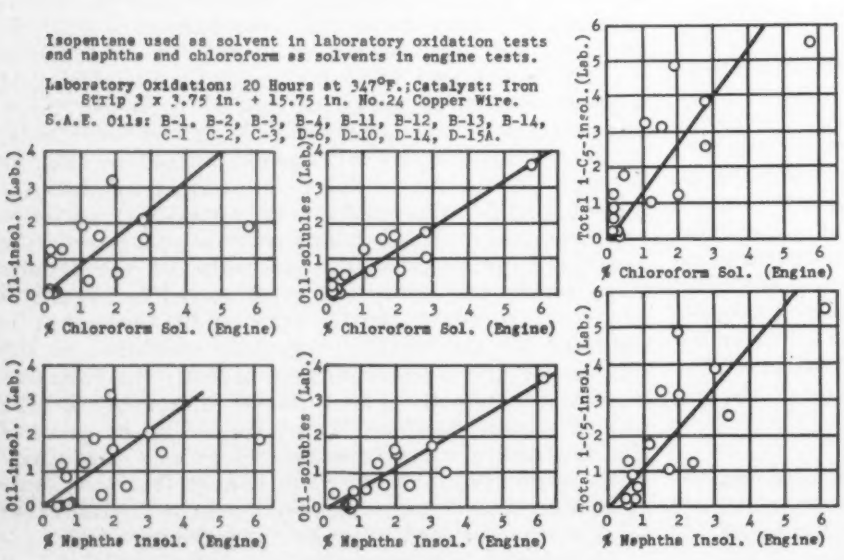
Isopentane used as solvent in laboratory oxidation tests and naphtha and chloroform as solvents in engine tests.
Laboratory Oxidation: 20 Hours at 347°F.; Catalyst: Iron Strip 3 x 3.75 in. + 15.75 in. No.24 Copper Wire.
S.A.E. Oils: B-1, B-2, B-3, B-4, B-11, B-12, B-13, B-14, C-1 C-2, C-3, D-6, D-10, D-14, D-15A.
Oil-Insol. (Lab.)
% Chloroform Sol. (Engine)
Oil-solubles (Lab.)
% Chloroform Sol. (Engine)
Total 1-C5-Insol.(Lab.)
% Chloroform Sol. (Engine)
Oil-Insol. (Lab.)
% Naphtha Insol. (Engine)
Oil-solubles (Lab.)
% Naphtha Insol. (Engine)
Total 1-C5-Insol.(Lab.)
% Naphtha Insol. (Engine)

FIGURE 5

Relation between precipitables from laboratory and engine tests

as a supplement to the full-scale engine testing of oils. The proposed use of the laboratory unit would be to classify the oils roughly as to their relative usefulness in the service for which they are tested. Some oils could immediately be judged unsuitable, while for others it may be desirable to impress more severe conditions in order to determine their suitability prior to subjecting them to full-scale engine or similar service tests.

Effect of Variations in Test Conditions

It has been emphasized that the test described was not intended to be a listing of certain fixed procedures and conditions which when applied to a lubricating oil would predict its service record. Due to the great variation in service conditions and to the continually greater demands on lubricating oils for most types of equipment, any laboratory test must be capable of considerable modification. This is particularly important in research work where first one and then another property of an oil will be emphasized and investigated. Where two or more possible solutions to a problem are indicated, it is frequently desirable to make the test conditions more severe to permit a choice between the two. Furthermore, while this test has been designed primarily to rate the stability of a lubricating oil from the standpoint of its ability to resist the formation of lacquer, oil-insoluble and precipitant-insoluble products, viscosity increase, and acidity, the test need not be limited to these uses.

The variables which must be studied in order to permit an intelligent choice of test conditions for a specific case are:

(1) The time of oxidation.

(2) The catalysts present during oxidation, and

(3) The temperature of the oxidizing oil.

By their use it is possible to make the test more or less severe and to emphasize one or another property of the oil. These obviously are not the only test variables but it is believed that they are the important ones for the majority of oils. Under certain conditions, the rate at which air is passed through the oil may be important. Since the mechanism of oxygen absorption by oil is a diffusion process, it is to be expected that at low rates of air circulation the diffusion process may be the rate-controlling factor and that, consequently, the rate of air bubbling may determine the rate of oxidation. However, as the rate of bubbling is increased the point is soon reached

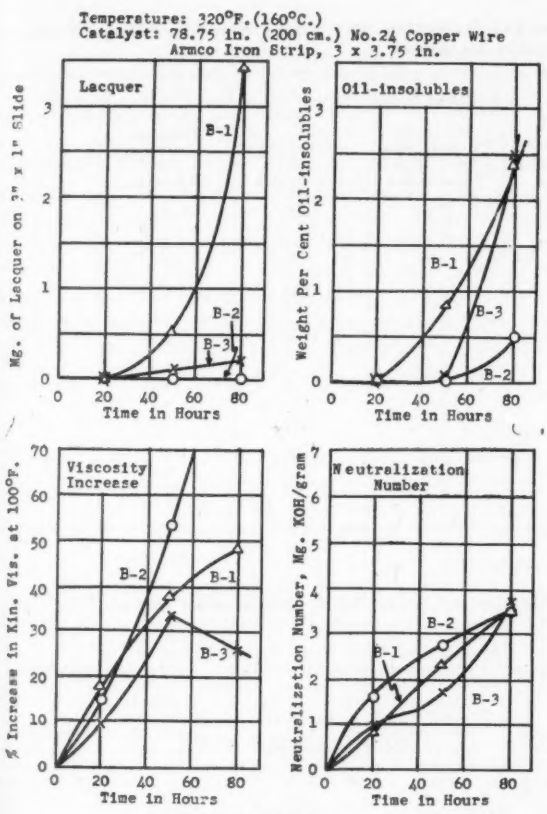

FIGURE 6

Effect of time on the oxidation of some S.A.E. cooperative engine test oils.

where the oil is saturated with oxygen and further increases in the circulation rate will only slightly affect the rate of oxygen absorption.

Time of Oxidation. From the standpoint of increasing the severity of a laboratory test or of establishing conditions which will yield a correlation with various service tests, the time of oxidation is probably one of the most important variables. This is true because, in general, the deterioration of an oil with regard to a given index of that deterioration will not be a linear function of time. This is not surprising in view of the fact that oxidation apparently proceeds by a chain mechanism. The presence of inhibitors and similar additives serves further to complicate this picture since these additives may function merely by retarding the initial oxidation or by breaking the chain reactions.

To illustrate the effect of time of oxidation upon the deterioration of lubricating oils, data are presented in Table 3 and Figure 6 relative to the oxida-

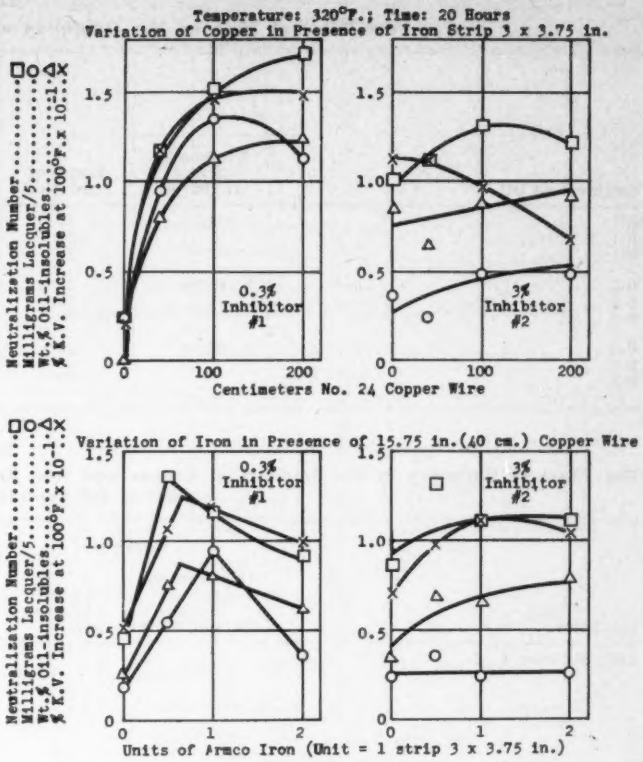
Temperature: 320°F.; Time: 20 Hours
Variation of Copper in Presence of Iron Strip 3 x 3.75 in.
Neutralization Number
Milligrams Lacquer/5
Wt.% Oil-insolubles
% K.V. Increase at 100°F. x 10
0.3% Inhibitor #1
3% Inhibitor #2
Centimeters No. 24 Copper Wire
Variation of Iron in Presence of 15.75 in.(40 cm.) Copper Wire
Units of Armco Iron (Unit = 1 strip 3 x 3.75 in.)

FIGURE 7

The effect of variation in amount of copper and iron catalysts on the oxidation of a conventionally refined Pennsylvania neutral containing oxidation inhibitors.

tion of 3 S.A.E. Cooperative Test Oils, B-1, B-2, and B-3. Here it will be noted that not only can increasing the time of oxidation be used to exaggerate the differences between oils but the order of rating of some oils may be reversed. For example, this is shown by the viscosity increase of oils B-1 and B-2. Under the conditions of test listed in Table 3, Oil B-1 showed a slightly greater viscosity increase after 20 hours than Oil B-2 (17.6 percent versus 15.0). However, at the end of 80 hours the instability of Oil B-2 has resulted in a viscosity increase of 331 percent because of the formation of large amounts of oil-soluble resinous matter, while Oil B-1 shows only 48.1 percent increase after the same period. These data point to the desirability of extending the time of oxidation when there is any doubt as to the relative merits of any selected pair of oils.

Effect of Catalysts. Catalysts are useful for accelerating oxidation tests, and it has also been found that they accelerate the oxidation of different oils to different degrees. Thus, some oils, oxidized in a glass apparatus in the absence of catalysts, may appear to have essentially the same stability, but may exhibit widely different stability characteristics when oxidized in the presence of a catalyst. Thus, a differentiation on the basis of oxidation stability may be more easily and reliably achieved by the use of suitable catalysts.

The choice of catalysts for use in laboratory tests designed to rate oils with respect to the oxidation stability which might be expected in service is obviously governed by the fact that certain metals present in engine lubricating systems are known to be catalytically active toward the oxidation reaction. These are principally iron and copper, with the lead introduced through the use of leaded fuels being a possible additional factor in some cases.

To illustrate the effect of these metals as catalysts

TABLE 3

The Effect of Time on the Oxidation of Some S.A.E. Cooperative Engine Test Oils

Engine Test Oil	Kinematic Viscosity at 100° F.	Hours of Oxidation	Results of Stability Test at 320° F. (160° C.) Catalyst: Armco Iron Sheet 3x3.75 In. + 78.75 In. (200 cm.) No. 24 Copper Wire				
			Milligrams Lacquer	Percent Oil-Solubles, Iso-C_5H_{12} Insolubles	Percent Oil Insolubles	Percent Increase in 100° F. Viscosity	Neutralization Number
B-1	126.3	20	0.1	0.14	0.00	17.6	0.85
B-1		50	0.5	1.12	0.82	37.8	2.30
B-1		80	3.4	1.56	2.38	48.1	3.50
B-2	88.54	20	0.1	0.00	0.00	15.0	1.58
B-2		50	0.0	0.15	0.00	53.3	2.70
B-2		80	0.0	5.14	0.49	331.	3.50
B-3	93.52	20	0.0	0.00	0.00	9.5	0.98
B-3		50	0.1	1.40	0.05	33.6	1.70
B-3		80	0.2	0.58	2.46	25.9	3.70

TABLE 4

The Effect of Variation in the Amounts of Copper and Iron Catalysts on the Oxidation of a Conventionally-Refined Pennsylvania Neutral Oil Containing Oxidation Inhibitors

Inhibitor	Catalyst		Results of Stability Test After 20 Hours at 320° F.				
	Centimeters (Inches) No. 24 Copper Wire	Units* Armco Iron	Milligrams Lacquer	Percent Oil-Solubles, Iso-C_5H_{12} Insolubles	Percent Oil Insolubles	Percent Increase in 100° F. Viscosity	Neutralization Number
0.3% Inhibitor 1	0 (0)	1	1.3	0.00	0.02	2.1	0.25
	40 (15.75)	1	4.7	0.22	0.80	11.8	1.15
	100 (39.38)	1	6.7	0.30	1.13	14.6	1.50
	200 (78.75)	1	5.6	0.32	1.23	14.9	1.70
	40 (15.75)	0	0.9	0.08	0.25	5.2	0.45
	40	0.5	2.7	0.21	0.75	10.7	1.35
	40	1	4.7	0.22	0.80	11.8	1.15
	40	2	1.8	0.18	0.62	9.9	0.90
3% Inhibitor 2	0 (0)	1	1.8	0.45	0.84	11.2	1.00
	40 (15.75)	1	1.2	0.41	0.65	11.0	1.10
	100 (39.38)	1	2.4	0.39	0.88	9.6	1.30
	200 (78.75)	1	2.4	0.31	0.91	6.8	1.20
	40 (15.75)	0	1.2	0.27	0.34	7.1	0.85
	40	0.5	1.8	0.37	0.69	9.8	1.30
	40	1	1.2	0.41	0.65	11.0	1.10
	40	2	1.3	0.40	0.79	10.4	1.10

* 1 Unit = 1 Sheet Armco Iron, 3 x 3.75 Inches.

TABLE 5

The Effect of Varying the Amount of Copper Wire Catalyst on the Oxidation of Some S.A.E. Cooperative Engine Test Oils

Engine Test Oil		Results of Stability Test After 20 Hours at 320° F. Catalyst: 1 Sheet Armco Iron 3 x 3.75 In. + Copper as Indicated				
	Centimeters (Inches) No. 24 Copper Wire	Milligrams Lacquer	Percent Oil-Solubles, Iso-C_5H_{12} Insolubles	Percent Oil Insolubles	Percent Increase in 100° F. Viscosity	Neutralization Number
B-11	0 (0)	0.0	0.00	0.00	23.5	0.30
B-11	40 (15.75)	0.1	0.00	0.00	24.2	0.60
B-11	200 (78.75)	0.4	0.49	0.40	33.3	1.15
B-12	0 (0)	0.7	0.02	0.12	13.5	0.80
B-12	40 (15.75)	1.9	0.36	0.53	28.7	2.50
B-12	200 (78.75)	1.7	0.24	0.58	22.8	2.45
B-13	0 (0)	0.0	0.00	0.00	8.1	0.53
B-13	40 (15.75)	0.1	0.00	0.00	9.6	0.83
B-13	200 (78.75)	0.1	0.43	0.15	12.8	1.05
B-14	0 (0)	2.1	0.55	0.40	31.4	0.70
B-14	40 (15.75)	13.0	1.26	1.70	62.0	3.35
B-14	200 (78.75)	3.9	1.01	2.08	57.4	3.45

TABLE 6

The Effect of Temperature on the Oxidation of Some S.A.E. Cooperative Engine Test Oils

Engine Test Oil	Kinematic Viscosity at 100° F.	Temperature of Oxidation	Results of Stability Test after 20 hours Catalyst: Armco Iron Sheet 3x3.75 In. + 15.75 In. (40 cm.) No. 24 Copper Wire				
			Milligrams Lacquer	Percent Oil-Solubles, Iso-C_5H_{12} Insolubles	Percent Oil Insolubles	Percent Increase in 100° F. Viscosity	Neutralization Number
B-11	42.01	320° F.	0.1	0.00	0.00	24.2	0.60
B-11		347° F.	1.5	0.64	0.59	52.6	1.00
B-12	37.54	320	1.9	0.36	0.53	28.7	2.50
B-12		347	1.1	0.52	1.27	45.7	2.60
B-13	38.23	320	0.1	0.00	0.00	9.6	0.83
B-13		347	0.1	0.06	1.23	12.6	1.10
B-14	22.46	320	13.0	1.26	1.70	62.0	3.35
B-14		347	10.2	1.67	3.20	41.1	3.50

and of varying the amounts of the catalysts, data are presented in Table 4 and Figure 7 on the oxidation of a conventionally-refined Pennsylvania neutral oil containing different oxidation inhibitors in the presence of varying amounts of iron and copper metals. It will be evident upon inspection of these data that for the same base stock the effect of the catalysts will be influenced by the type of inhibitor which is present. Thus, the Pennsylvania neutral containing Inhibitor 1 was much more sensitive to the amount of copper present than was the same oil with Inhibitor 2. Furthermore, for the same oil and inhibitor the effect of different catalysts may be markedly different. For example, the tendency of the neutral containing Inhibitor 2 to increase in viscosity decreases with increasing quantities of copper, while iron has the opposite effect.

Similarly, in Table 5 and Figure 8, some data are presented to show the effect of increasing the quantity of copper metal on the oxidation of four S.A.E. Cooperative engine test oils in the presence of a fixed amount of iron metal. These results illustrate clearly the effect of the copper catalyst. The oils show far greater difference in stability in the presence of copper than in its absence. However, while the presence of a relatively small amount of copper has a marked effect, these oils appear to be rather insensitive to the further addition of copper.

Temperature of Oxidation. Increasing the temperature of an oxidizing oil invariably results in an increased rate of deterioration of the oil and consequently is a ready means of accelerating the testing of oils. However, there is obviously a limit to the temperature that may be used and, in general, it would seem to be safer to choose a temperature in the range of that which might be expected in service, and to achieve correlation with service results by adjusting the amount of catalyst and the time of oxidation. Data presented in Table 6 indicate that the effect of raising the temperature of oxidation 27° F. (15° C.) on the oxidation of four S.A.E. Cooperative Engine Test Oils is similar in some respects to increasing the amount of copper catalyst (Table 5).

Other Applications

The stability test described is not necessarily limited to the uses so far indicated. It has, for example, been used to investigate the corrosivity of oxidizing oil toward different metals, including bearing alloys, by immersing a sample of the metal in the oxidizing oils. Due to the absence of any "wiping" effect such as is encountered in engine bearings, the data so obtained need to be critically examined. Thus, it would seem that a bearing surface which shows no

TABLE 7

Bearing Corrosion Measurements by Means of the Stability Test

OIL	Copper-Lead Bearing Corrosion			Cadmium-Nickel Bearing Corrosion Stability Test* Mg./Sq. In.
	Chevrolet Engine Test g./Bearing Half	Stability Test* g./Bearing Half†	Stability Test* Mg./Sq. In.	
B-1	0.31	0.022	4.0	0.1
B-2	1.13	0.167	30.5	56.5
B-3	0.27	0.046	8.5	0.1
B-4	0.21	0.056	10.2	33.6
D-6	0.03	0.000	0.0	.....
D-14	0.41	0.159	29.0	....

* **Stability Test Conditions:**—Temperature: 347° F.; Time: 20 Hours; Catalysts: Armco iron strip 3 x 3.75 inches, 15.75 inches No. 24 copper wire, and either 2.2 sq. in. copper-lead or 3.1 sq. in. cadmium-nickel bearing surface.
† Conversion of laboratory test values in mg./sq. in. to g./bearing half is based on an area of 5.45 sq. in./bearing half.

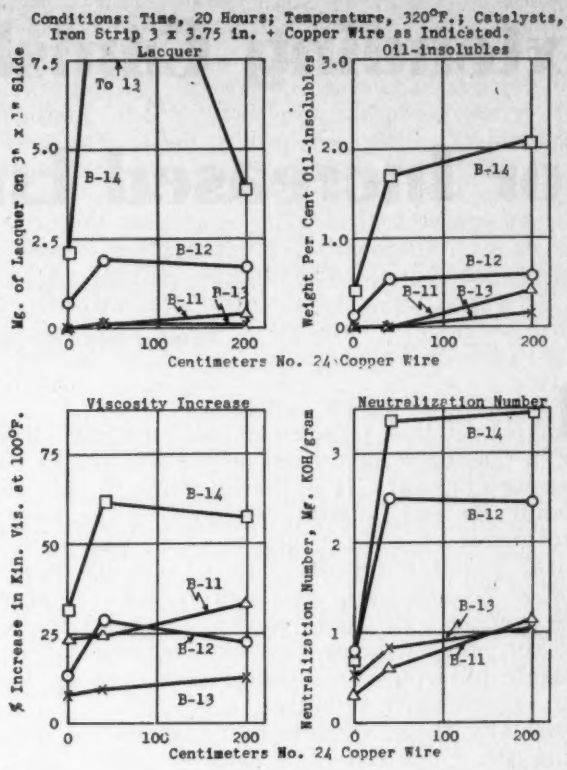

FIGURE 8

The effect of varying amount of copper catalyst on the oxidation of some S.A.E. cooperative engine test oils.

corrosion in the stability test should be carefully examined for evidence of the presence of a sulfide or other coating on the metal which might not be able to protect the bearing when used in engines where the wiping effect might prevent the formation of the protective coating. Data obtained by means of the stability test on the corrosiveness of some of the S.A.E. Cooperative test oils are presented in Table 7. While the amount of copper-lead bearing corrosion is less in the laboratory test, the relative ratings of the oils are essentially similar to those given by the bearing corrosion results from the Chevrolet engine test.

One use in which the apparatus has proved well suited is for the investigation of oxidation inhibitors and the relative evaluation of these materials in different base stocks. It has also been used to a certain extent to study the effect of detergents upon the formation of insoluble matter when the oil containing the additive undergoes oxidation. By means of a suitable modification other specific factors bearing upon oil deterioration may be evaluated.

ACKNOWLEDGMENT

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Extending Camshaft Operating Life For Increased Engine Power Output

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Presented before the California Natural Gasoline Association

MANY of the compressor and pumping stations now in operation have been on the line for as much as a score of years. It is the intention of this paper to point out and illustrate methods of checking the performance of some types of cams which, in the natural gasoline industry, have actually required little or no attention, and therefore have received none over such extended periods of operation. Now, however, natural wear plus the demand for every available horsepower of compressor capacity forces us to search more intently.

Normally there are but two reasons for investigating the condition of a cam. If, when new, an engine does not deliver its rated power output or valve troubles are encountered, the cam design or timing might be questionable; but this rarely happens. The other most plausible reason may occur some years later when visual wear of the cam itself, or of its follower, becomes noticeable and causes the mechanic to become suddenly cam-conscious. The more common forms of cam wear can be divided as follows:

1. Pock marks of corrosion are usually most prevalent on the front or lifting faces having high unit pressures at point of contact with roller followers. As the percentage of total surface area destroyed is usually small, this condition does not necessarily mean that the cams are no longer functioning with a fair degree of efficiency, but, from this point on an accelerated rate of wear on both cams and rollers may be expected.

2. A more or less smooth and even wear upon both sides and top of the cam lobe may occur. This type of wear will cause an appreciable falling off in power with no ready means of ascertaining its cause or even its presence.

3. Wavy, irregularly worn places on cam faces can be easily detected. The common causes are continuous operation with excessive push rod clearance, sticky valves with a tendency to "hang up" at certain points, or improper valve spring tension.

There are three principal methods of checking cam performance. The first two described have the advantage of making camshaft removal from the engine unnecessary but do not permit such complete examination as does the third.

1. With the engine cold so that there are no rapidly changing temperatures of parts affecting push-rod clearances, carefully set same to normal operating clearance. Arrange devices on both inlet and exhaust valves which will indicate when they start to open or become completely closed. Then slowly bar over the engine noting at which points, in terms of degrees of flywheel rotation, the valve events take place. Should the flywheel be unmarked for valve timing, a steel tape laid around the wheel from the stationary index to H.D.C. or C.D.C. can be used to measure the intervening distance and from this can be calculated the respective valve timing.

2. While maintaining the engine "on the line" and under full load, indicator stop cards or valve cards may be taken. By using a very light indicator spring to magnify the bottom of the conventional power card, an analysis may be made of the scavenging or exhaust valve action, the inlet or filling strokes, and the beginning of the compression strokes. From these diagrams a diagnosis of valve, air-intake, or exhaust troubles may be made.

3. A third and quite accurate method of cam checking involves the removal of camshaft from engine and placing of same in a testing jig. A spe-

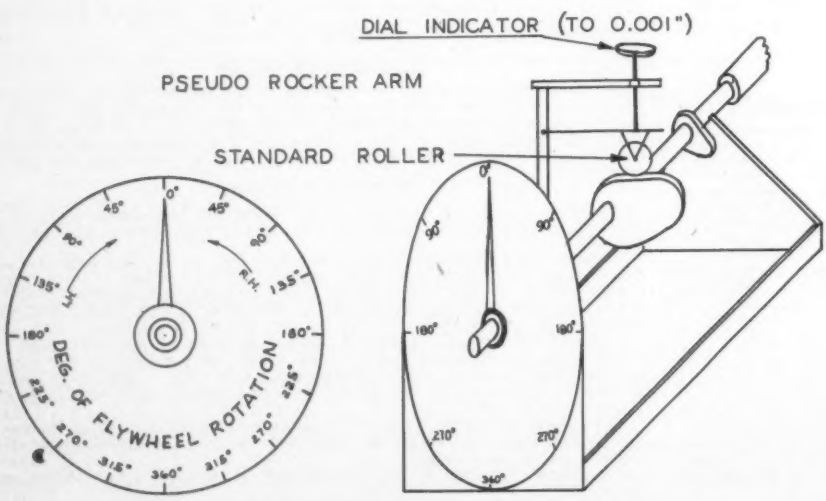


FIGURE 1
Schematic views of camshaft testing jig.

cial dial comprising 720° of flywheel rotation for one complete camshaft rotation with an accompanying adjustable index permits direct reading of valve events as produced by the respective cam.

Cam-Testing Jig

Figure 1 is a simple schematic diagram of such a cam-testing jig. This shaft and both cams are forged integrally so that the setting to one reference point in reality controls all four events; namely, the opening and closing of both the intake and exhaust valves. Operation consists of turning the camshaft so that the roller-follower rests upon the intake cam base circle with the attendant dial indicator set to read 0.000 inch. Rotate camshaft in the proper direction until the roller is starting to be lifted by the gradual incline of the cam ramp and the dial indicator reads +0.020 inch which rorresponds to the 0.020-inch engine valve push rod clearance. Now set the pointer index at 10° ahead H.D.C. and tighten to shaft as this is the point of intake valve opening and all other valve events are read from the position of the index when the dial indicator reads +0.020 inch above the base circle on the respective cam ramps.

This figure may be made very elaborate, if deemed justifiable, by mounting a roller and a 1.000-inch range dial indicator above each cam in the same relative positions as in the actual engine. On the other hand, once a satisfactory cam of known characteristics has been secured, a single dial indicator with the pressure point bearing directly upon the cam can be used for checking questionable cams. However, the correlation between such a jig and actual engine performance must be worked out to insure proper interpretation.

Figure 2 is an illustration of typical cam characteristics. Displacement or cam roller lift in inches is plotted against degrees of camshaft rotation. The dotted line represents the theoretical movement desired but which must be changed until it is represented by the heavy line of gradually increasing and decreasing slope. Of course, fast valve action is desirable but it is governed by the mass and inertia of the moving parts, or, in reality, by the mass and acceleration. The acceleration curves must therefore be given consideration or a rapid and uneven wear of cams will result. Of more immediate consequence will be the pounding of valves and seats unless valve closure has been carefully decelerated at point of contact.

A cam-testing jig is of considerable assistance in determining the amount of "ramp" or very slow lift required in absorbing the push-rod clearance without excessive shock as well as the reverse action or depositing of valves upon their seats without a deleterious pound. Most cams of late design, particularly those using a roller follower, do not depend upon a straight tangential radius or the straight part of the cam face forming a perfect tangent with the base circle. To avoid the resultant shock a "transition radius" or "ramp" is employed as depicted in Figure 8.

Two Master Cams

This figure is presented to show the comparative shape and size of the actual cam to that of the master. An explanation is in order. After the experimental stage was passed and actual production entered into, two master cams were made, one each for the intake and exhaust cams. To insure a high degree of precision and maximum speed of grinding a 22-inch wet wheel turning at 1000 revolutions per minute was used. A 3-inch roller followed the master cam which rotated at 20 revolutions per minute. These masters were attached to the camshaft undergoing the grinding by means of a key and an adjustable indexed centering hub and pin. The whole assembly was mounted upon a large external power grinder in such a manner that the camshaft and master could rock back and forth while being held with a constant pressure against the grinding wheel. The precision was within ±0.001 inch, quite satisfactory for large cams. It is of importance too as a variation of base circle or of ramp near point of intake-valve opening, can effect the timing of valve events at the ratio of ¾° of flywheel rotation per 0.001-inch deviation. Base circles have been found as much as 0.008 inch out of round and in such places that actually resulted in the entire camshaft being 6° out of time with a noticeably decreased power output even though properly timed according to conventional and available standards.

The ensuing indicator diagrams were taken in a conventional manner, using 180 pounds per square inch, gauge, per inch spring for the power cards and a 10 pound per square inch, gauge, per inch spring for the valve cards. The valve cards merely represent the bottom of the power cards but enlarged at the

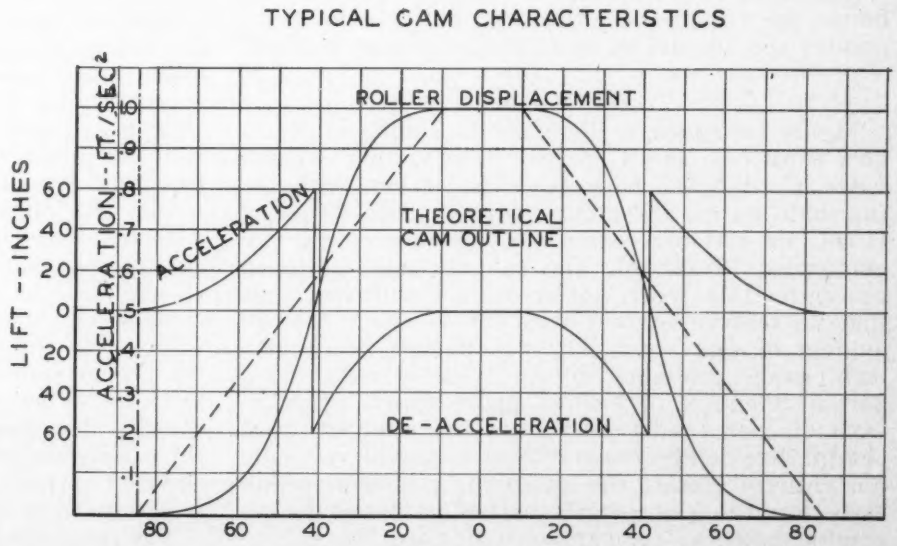


FIGURE 2
Camshaft rotation—degrees.

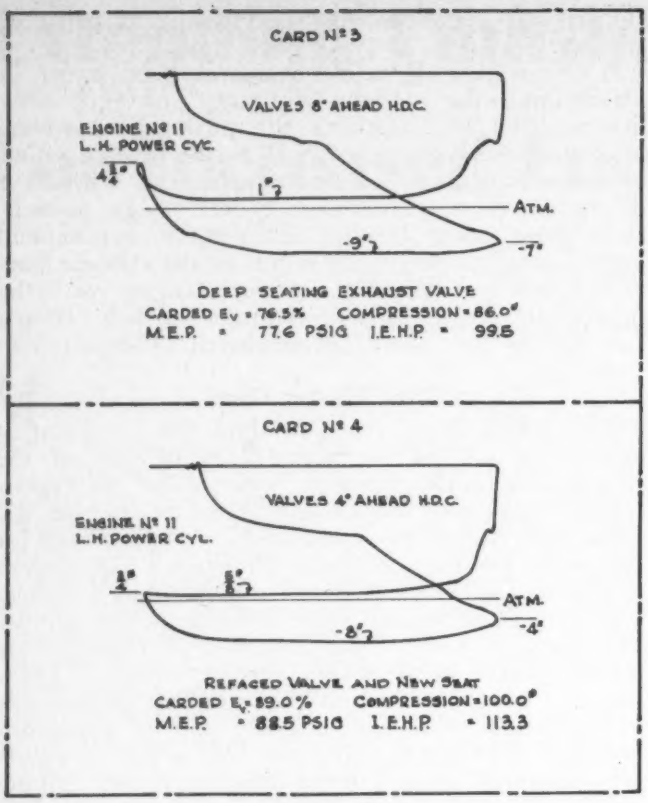


FIGURE 3
Effect of deep seating exhaust valve.

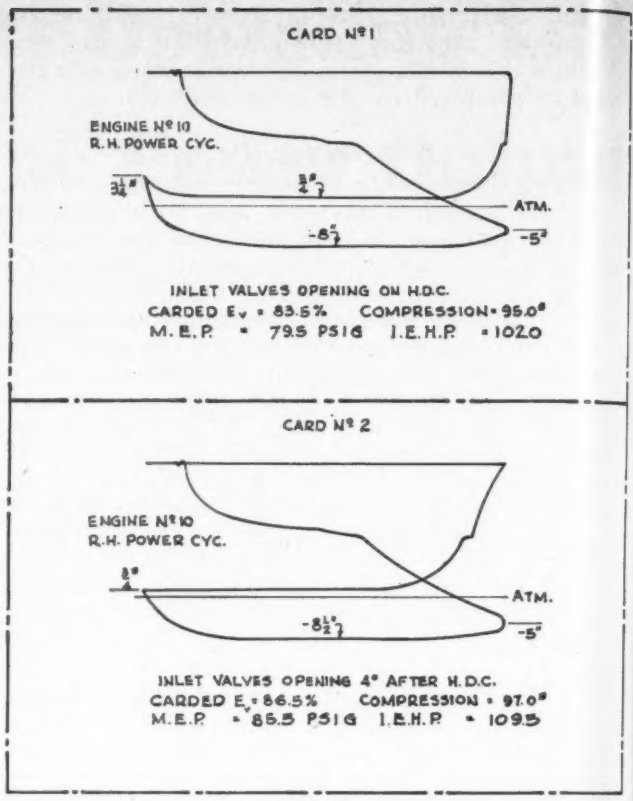


FIGURE 4
Effect of extreme retarding of both cams to compensate for hardly noticeable wear.

ratio of 18 to 1. Of course, the top one third of the valve cards must be disregarded as compression was being undergone by a rubber snubber placed around the piston rod to gently snub and completely stop its movement during the time that the cylinder pressure exceeded approximately 8 pounds per square inch, gauge. Thus the top line, or explosion stroke, must be completely disregarded. The line falling from the upper right to the left represents the actual pressure within the cylinder during the exhaust or scavenging stroke. The reversal of the continuation of this line, from left to right, indicates the cylinder vacuum during the intake or filling stroke. Its second reversal, from right to left, shows the pressure buildup from negative to positive during the beginning of the compression stroke. The earlier the compression stroke crosses the atmospheric line the better the volumetric efficiency, and therefore, the greater the amount of combustible charge induced.

Worn Cam

Figure 3 is shown to illustrate the combined effects of a worn cam and a slightly deep seating exhaust valve. Card No. 3 is a valve card taken with the camshaft set for the intake valve to open 8° ahead H.D.C. or within a reasonable tolerance of the recommended 10° ahead. The exhaust cam displayed no appreciable wear, yet it existed sufficiently so that no reserve contour was left to offset a small amount of seat wear. The 4¾ pounds per square inch, gauge, pressure in the cylinder indicated a partial retention of burned gases which upon re-expanding prevented entry of a portion of the fresh charge. Replacing of seat and replacing of valve did not entirely correct the situation, closure was still early. Retarding of the camshaft 4° produced the net results shown by comparison with Card No. 4.

Cards No. 1 and No. 2 of Figure 4 show the effect of retarding another camshaft 4°. This cylinder was weak but examination of valves, seats and camshaft disclosed no appreciable wear. Valve cards and checking of camshaft timing proved that cam wear did exist. It was the investigation of conditions like these that led to the fabrication of the improvised cam-testing jig and experimentation to determine how late the intake valve could be closed in order to secure a maximum of combustible charge yet lose no appreciable amount of this charge in case the engine should operate considerably under speed.

New camshafts were secured and their performance and characteristics carefully checked in an engine selected as a "guinea pig" because of its accurate indicator motion and facilities for varying the compression loading. Camshaft timing was again checked in many settings, both early and late, and the indicator valve cards analyzed as well as power cards being compared. The camshaft we desired would require three changes: an earlier-opening and closing exhaust, and a later closing intake. Graphically the intake valve was closing at about the proper time, but actually it seemed many degrees early.

Our first job was to build up one side of each cam, without excessive distortion from heat. The opening side of the exhaust cam was built up slightly, the closing side of the intake cam, more. Then both cams were ground, one half at a time, using small wheels and the same size follower and maintaining the proper cam contours, follower acceleration, and velocity. When the job was done, which included considerable hand filing, checking in the jig, etc., the cams were ground a total of 0.060 inch under, but the cam spread and their relationship to each other was somewhat changed.

The results were as shown in Figure 5. The engine

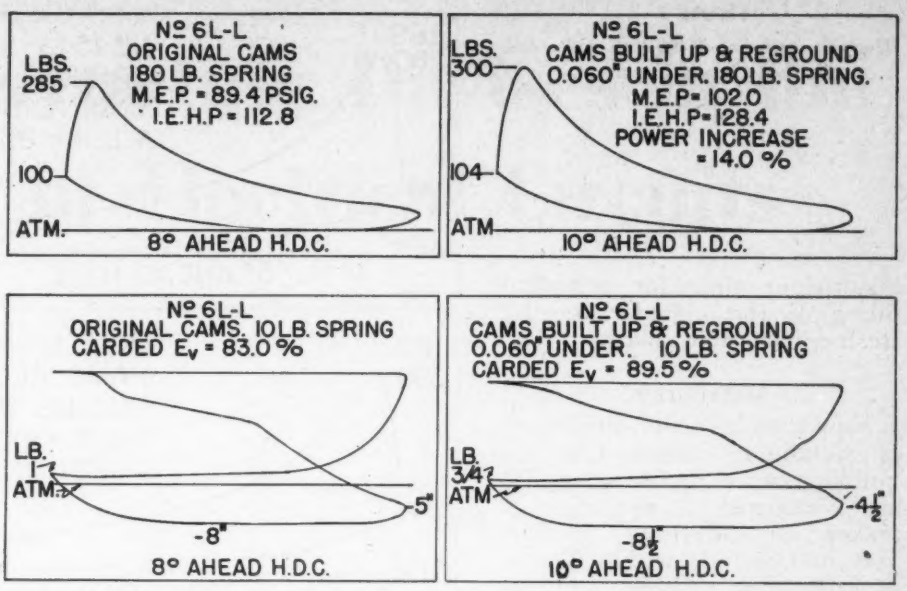


FIGURE 5

Effect of rebuilding and regrinding 0.060-inch under.

had been one of our best. Now, with 14 percent additional power output would the frame and bearings hold up, and if so, how about the heat transfer through the rings? Well, to shorten the story, that was 25 months ago. To date there has been no unusual maintenance, and bearings, rings and valves are holding their own. Of course, the maximum explosion pressures and total thrust upon the bearings is no greater under the greater load at rated speed than is sometimes encountered at subspeed operation. This had been predetermined.

Maximum Power

It is desired to stress one point. In all these cases where comparative cards are shown the engines always had timing and fuel mixtures adjusted for maximum power, and were loaded but operating at the same rated speed unless otherwise specified. With the exception of the camshafts no mechanical changes, even that of a spark plug, were permitted while these tests were being made.

As the machine shop in which the original work of regrinding was done, two years ago, was rapidly being converted to what we now term 100 percent defense work, we did not then have sufficient time to completely explore the field for a suitable hard surfacing material. We underground one set of camshafts sufficiently to make our desired changes and found it necessary to go to the extent of 0.400 inch undersize in base-circle diameter. They, too, proved quite satisfactory so a year ago after having had some half dozen rebuilt and converted shafts in successful operation for a year, the work was resumed.

Figure 6 includes both power and valve cards taken on an engine before and after some of the heavily underground cams were installed. The valve timing, acceleration, etc., are the same as for the cards shown in Figure 5 with the rebuilt cams.

Figure 7 displays power cards from a unit which for various reasons is sometimes operated up to 10 percent above rated speed. No adjustments were made between the taking of Cards No.2 and No. 3 as is shown by the apparently late ignition of Card No. 3. The lowered compression pressure, maximum explosion pressure, and M.E.P. show the effect of

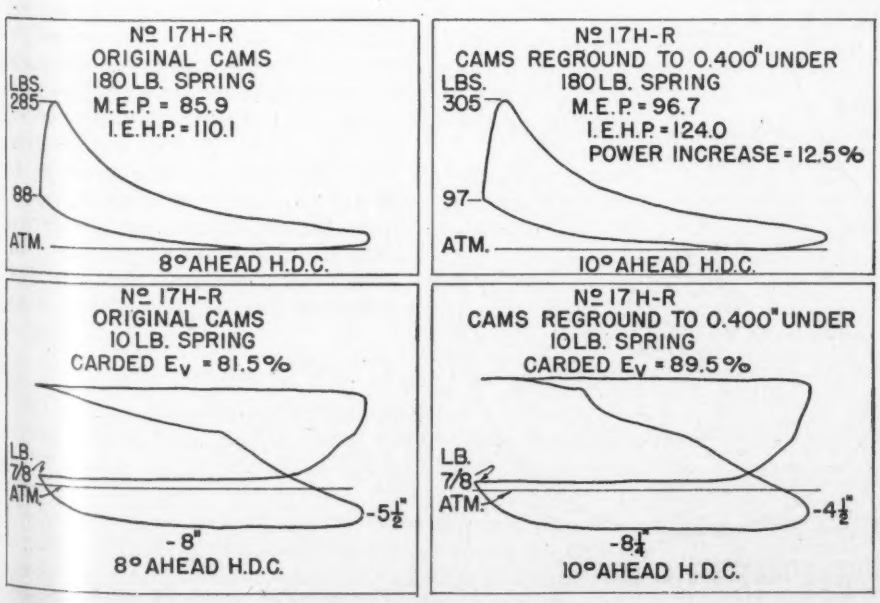
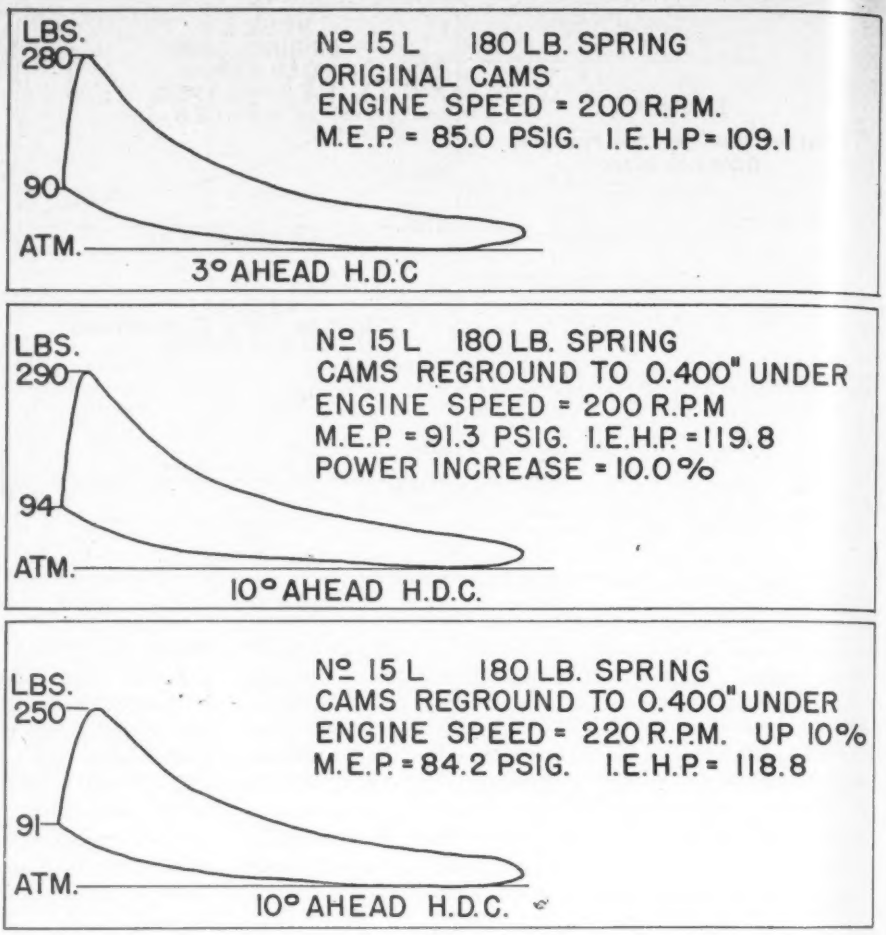


FIGURE 6

Effect of regrinding 0.400-inch under.

FIGURE 7

Effect of regrinding 0.400-inch under and increasing speed 10 percent.



insufficient time for complete filling of the cylinder by the fresh combustible charge.

Metallurgy

Now then, to touch the fringe of metallurgy envolved in rebuilding cams. As far as results are concerned it apparently makes no difference whether you undergrind, within limits, or completely rebuild and regrind—it is the shape of the cam that counts.

Most cams are forged steel, usually a low-carbon steel, some are surface hardened, some are not. The hardness may vary from 130 in some to 600+ Brinell in others. The average of my experience has been under 200 Brinell. At this hardness the cams are soft enough to have undergone wear, apparent or otherwise, in 10 years of operation. A good chromemoly rod, applied with either torch or arc, may attain a hardness of 300 Brinell. The real hard facing alloys are fine, if your priority will secure them and you can get wheels to grind it. The irregular shape of camshafts cause most of the heat treaters to talk about distortion and the added cost of straightening within ±0.003 inch which is not close enough.

Plain flame-hardening performed by experienced men and followed by an air quench, then stress relieving, was the answer to our problem, and it raised the Brinell hardness of the cam faces from 190 to 500+ with no distortion.

A natural question arises, "Is it worth while to go to the necessary expense and work at this time to revamp some old engines?" The answer is if installed direct-connected compressor capacity is worth $50.00 per boiler-horsepower now, our additional boiler-horsepower thus gained has cost much less than 10 percent of what it is worth.

It is my desire to mention the assistance in this work of Mr. Bennett Schock, of General Petroleum Corporation, for his timely suggestions, untiring assistance, and limitless patience in testing of the "guiena pig" engine, and Mr. Arthur Bender, of H. D. Biggs & Son, for making available his experience in producing that funny looking master cam and really placing this cam regrinding on a production basis.

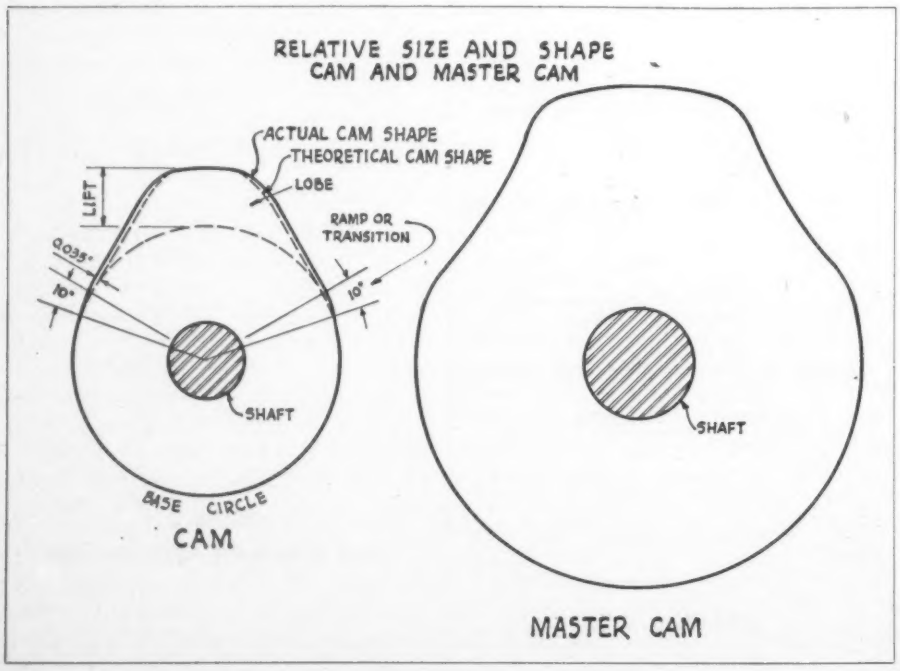


FIGURE 8

Comparison of actual cam and master cam.

Use of Interrupting Devises in the Clearing of Electrical Circuits

WAYMAN A. HOLLAND
Switchgear Division, General Electric Company

BECAUSE there is always the possibility of a fault, or short circuit, in any electric circuit, interrupting devices are necessary to clear such faults which might otherwise damage equipment. The interrupting device must have adequate "IC" (interrupting capacity) to clear the circuits safely and quickly, and must also have sufficient momentary capacity to withstand the effect of the maximum short-circuit current the circuit can develop.

It is necessary to know how to calculate the short-circuit current and the following describes a simple method for doing it. Ratings and reactances of the machines involved must be known (data on generators, transformers, and motors can be obtained from their manufacturer); and also the reactances of circuits (calculated from rules not given here).

Step 1: Ascertain the total reactance to the point of the fault.

(a) *"Percent" and "Per-unit" terms.*

It is common practice in a-c calculations to refer to reactance only, usually in percent. This means that the reactance is such that with rated current the drop due to the reactance is that percentage of the normal voltage. More recent practice is to express the percent value as a decimal, a 12 percent reactance, for example, becoming a 0.12 per unit (p. u.) reactance.

(b) *Conversion to base kva.*

In data giving percent or per unit reactance, the value is based on the kva rating of the machine referred to. The p. u. value, based on the normal current at one kva, will be different at any other. Consequently, before combining the reactances of a number of elements of a circuit, it is necessary to convert them to a common or *base kva.* For this base kva any convenient figure may be chosen. Usually it is the kva rating of one of the machines on the system, or the total kva of the system, or of the part of the system being considered.

Conversion is accomplished by dividing the base kva by the kva rating of the machine in question and multiplying the result by the given p. u. value.

(c) *Conversion of ohms to p. u.*

Sometimes, especially of cables, the reactance is given in ohms. This is changed to p. u. terms by the formula:

$$\text{p. u. at base kva} = \frac{\text{base kva} \times 1000 \times \text{ohms}}{\text{Volts } 2}$$

(d) *Total reactance to point of fault.*

This is found by adding the p. u. values of the various elements in series, after converting them to the base kva.

Where two or more generators or circuits operate in parallel, their individual reactances must be combined into a single equivalent for adding to other reactances in series. This is equal to the reciprocal of the sum of the reciprocals of the individual p. u. values, such as for example:

$$\frac{1}{\frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3}}$$

where X_1, X_2, and X_3 are the values of the reactances of the individual machines (all converted to the base kva).

Where low-voltage devices are to be installed in a system served by a power transformer fed by a system whose total reactance to the transformer is not known, it is sometimes the practice simply to assume the transformer as the source, and thus to assume the transformer reactance as the total. This is conservative practice as it gives the maximum possible short-circuit current.

A practical assumption is that the interrupting rating of the device controlling the primary (usually known) is the limit of power available. This then is the base kva, with p. u. reactance of 1.0. The p. u. of the transformer, given at the transformer kva rating, converted to the base kva and added to the unity of the base reactance, give the total reactance to the transformer secondary terminals.

Step 2: Find the symmetrical short-circuit current by dividing the normal base current (the normal current corresponding to the base kva) by the total p. u. reactance.

Motor Contributions: When short circuits occur, mo-

Multiplying Factors and Apparatus Reactances to Use for Interrupting-Device Selection

Interrupting Device	MULTIPLYING FACTOR[1]		REACTANCES		
	Interrupting Capacity	Momentary Current Capacity	Synchronous Generators	Synchronous Motors and Converters	Induction Machines
Fuses (15,000 volts and below, installed remote[2] from generating station or substation bus).....	1.2[3]	1.2[3]	Subtransient	Subtransient	Subtransient
Low-Voltage Air Circuit Breakers.....	1.25	1.25	Subtransient	Subtransient	Subtransient
Power Circuit Breakers (8-cycle opening).....	1.0	1.6[3]	Subtransient	[4]	[5]

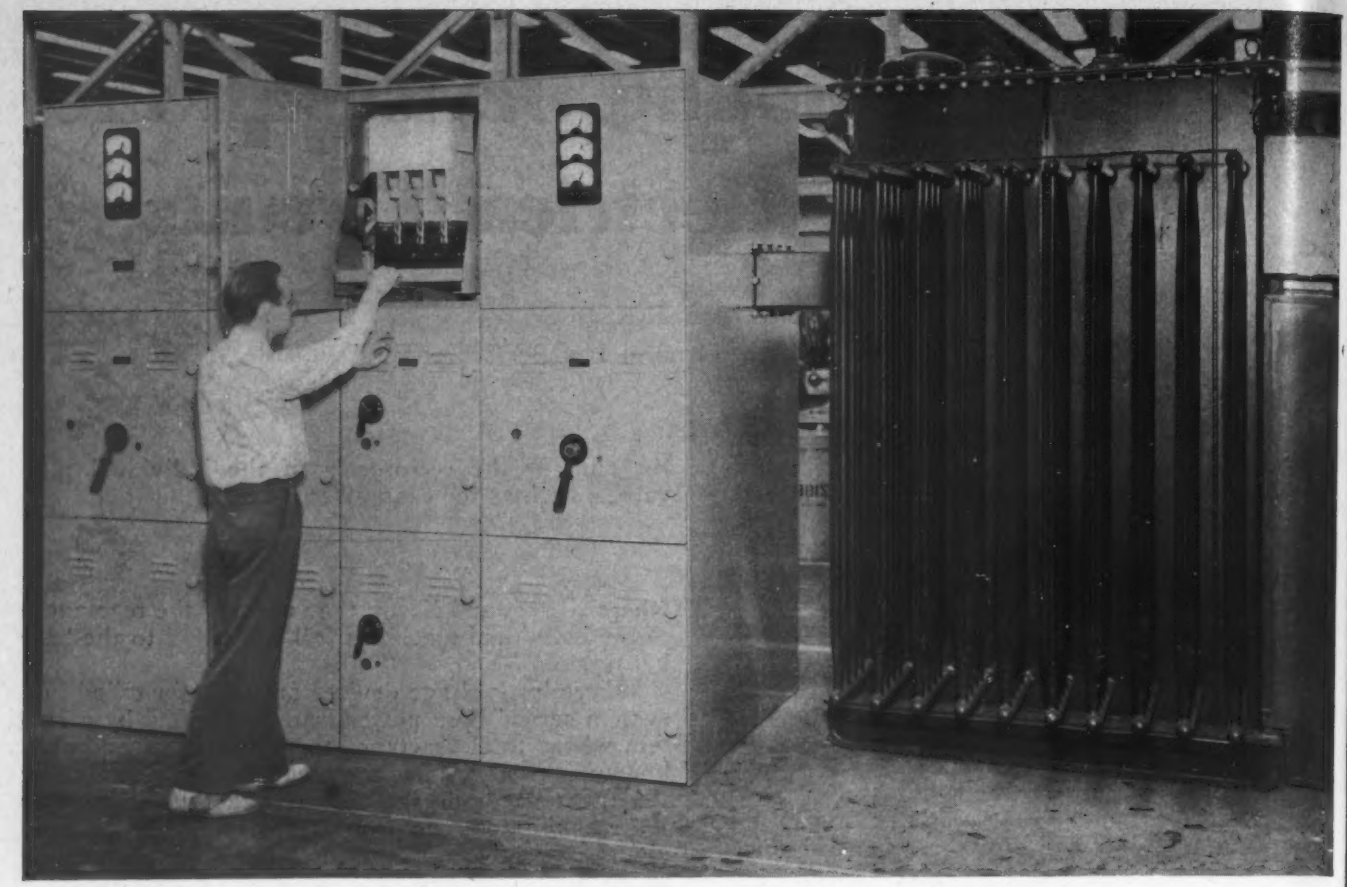
[1] The symmetrical short-circuit current calculated as explained in the text is to be multiplied by the factors given in this table for finding the required capacity of the interrupting devices to be selected.

[2] "Remote" means at sufficient distance from the generator or substation bus that the ratio of the over-all reactance to the over-all resistance does not exceed four. Under other conditions the multiplying factor should be 1.6.

[3] This factor of 1.6 is for the general case, for power circuit breakers. In circuits at 5,000 volts and below a factor of 1.4 can be used, unless current is fed predominantly by directly connected synchronous machines, or by synchronous machines through current-limiting reactors only.

[4] For synchronous motor and synchronous converter symmetrical short-circuit current contribution the following reactances should be used for power circuit breaker selection:
For interrupting capacity.....Transient reactance
For momentary current capacity.....Subtransient reactance

[5] For the interrupting capacity of power circuit breakers the short-circuit current contributions of induction machines are not considered; for calculating the momentary current capacity, the subtransient reactance is used.



Indoor unit substation with drawout air circuit breakers, and self-cooled 3-phase pyranol transformer, 122 kva, 13.8 (delta) to 440 volts, 60 cycles, GE Type HT.

tions, equal in each case to the motor normal current divided by the motor subtransient p. u. reactance.

Step 3: (Final). Total asymmetrical short-circuit current.

At the inception of the short circuit, there is usually an "offset" component added to the symmetrical current of Step 2. This decays quite rapidly, but its addition to the symmetrical current makes up the total current which must be taken into account in the application of interrupting devices. The value of this total current is calculated by multiplying by certain factors summarized in the tabulation and explained as follows:

(a) *Fuses (15,000 volts and below):*

Where these are installed remote from a-c generators, the required interrupting capacity is found by multiplying the calculated symmetrical short-circuit current by 1.2. "Remote" in this case means, applied at sufficient distance from the generator or substation bus, that the ratio of over-all reactance to over-all resistance does not exceed 4. Under other conditions, the multiplying factor should be 1.6.

The motor contributions should be added before applying the multiplying factor.

(b) *Low-voltage air circuit breakers (600 volts and less).*

For both the interrupting and the momentary current capacity required, multiply the symmetrical short-circuit current by Step 2 (after adding motor contributions) by the factor of 1.25.

With the modern breakers properly coordinated for fast interruption, a "cascade" or "back-up" arrangement may be used to permit the use of backed-up breakers for short-circuit currents in excess of their interrupting ratings. In this arrangement the breaker connected directly to the source of power must have full interrupting capacity equal to 1.25 times the calculated symmetrical short-circuit current. The second breaker in the cascade, backed up by the first, need have only half this capacity (that is to say, it may be applied up to twice its interrupting rating), while a third breaker, doubly backed up by the first, or main, and the second breakers, need have only one third as much (or it may be applied up to 300 percent of its interrupting rating).

A cascade arrangement clearly results in an economy in investment of breakers, but it should be employed only with properly coordinated breakers.

(c) *Power circuit breakers*

The interrupting-speed rating of power circuit breakers most commonly used is 8 cycles, and for such breakers the multiplying factor for interrupting current capacity is 1.0.

In addition to the required interrupting capacity, these breakers must have a momentary capacity sufficient to withstand the total inrush current. For general cases this is 1.6 times the calculated symmetrical current, but for circuits at 5000 volts and below, unless the circuit is connected directly to generators, or to generators through reactors only, this multiplying factor is 1.4.

Contributions from induction motors may be neglected in figuring the interrupting capacity of power circuit breakers, but they must be added to the symmetrical current before applying the multiplying factor to get the momentary-current capacity.

In the case of synchronous motors, interrupting-current contributions are based on transient reactance, while the momentary currents are based on subtransient reactance.

Method for Detailing Pipe Bends Extending in Two Planes

VERY frequently, the draftsman working on power-plant piping and ship piping layouts encounters the problem of determining the length of a pipe which extends in two planes. The common method of solution involves layout and projection which may be lengthy and laborious. The method derived and explained here has been found by the author to be both direct and simple.

angles BEC and BED. It then follows that:

(1) $\text{Cos } z = \frac{BE}{BC}$

But, $BE = BD \text{ Cos } x$; and $BD = BC \text{ Cos } y$

Hence, $BE = BC \text{ Cosy Cos } x$

By substitution, formula (1) becomes,

(2) $\text{Cos } z = \text{Cos } x \text{ Cos } y$.

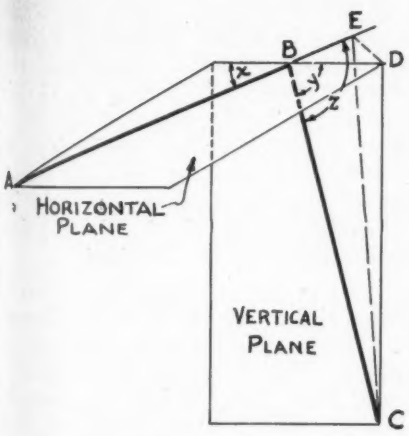


FIGURE 1

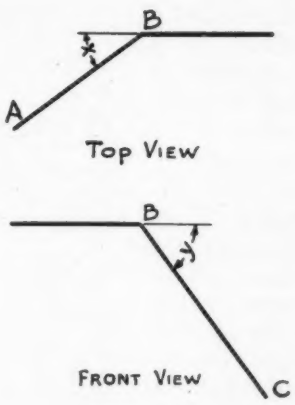


FIGURE 2

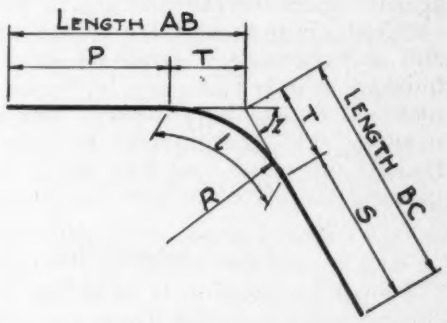


FIGURE 3

Figure 1 is a pictorial view showing lines AB and BC intersecting to form the angle z. Angles x and y are formed by the intersection of lines AB and BC with the horizontal.

Figure 2 is an orthographic projection of these lines. The top view shows the true length of AB, while the front view shows the true length of BC.

Figure 3 is the true layout of the pipe. In order to determine lengths in this figure, we must know angle z. The formula for angle z is derived from Figure 1 as follows:

Construct a plane through DC, perpendicular to the line AB. This forms two right angles at E;

Formula (2) is in convenient form for use in detailing the pipe shown in Figure 3.

To illustrate the application of this formula, we shall solve the following problem:

Ab = 10′ 3″ BC = 12′ 5″ x = 50° y = 65° R = 60″

By formula (2), Cos z = (Cos 50°) (Cos 65°) = .2716

Angle z = 74° 14′

Referring to Figure 3, T = R Tan z/2 = 2′—11 13/32″

P = 7′—3 3/32″; S = 9′—5 3/32″

$L = \pi Rz/180 = 6'—5\frac{3}{4}''$

The total length of pipe will then be 23′—1 15/16″

Thus, Formula (2) lends itself to valuable use when combined with standard formulas.

Proper Installation and Care Lengthen V-Belt Life

ELTON STERRETT

EVEN more vital in V-belts than in tires, rubber is the flexing agent, binder and wearing surface, and without it the continuous type of V-belt would fall far short of performing its part in keeping equipment of the refining industry turning.

Rubber binds together in a tenacious yet yielding bond the cords which give the belt its resistance against stretch, it forms the outer section which must elongate at each sheave distortion and return to normal length on the straight-away, it powers the gripping areas which contact the faces of the sheave groove, and it protects the fabric or cord carcass against water, weather and grit. Rubber, natural or synthetic, is indispensable to the continuous V-belt, and shortages or restrictions in rubber supply are quickly reflected in V-belt stocks. This condition makes it imperative for every user of V-belts, every operator whose equipment includes one or more of these vital units, to adopt every means which will prolong the life of present equipment.

Installation

Proper installation is of prime importance in obtaining maximum life from the drive. Because the V-belt is highly flexible in all directions save parallel to the drive, in contrast to the relative lateral rigidity of flat belts, some users seem to be of the opinion that the belts will automatically compensate for slight misalignment, shaft center variations and other supposedly minor inaccuracies.

True, the V-belt will take up these shortcomings in drive planning and installation, but only on the payment of a high premium in shortened life. If the V-belt drive be considered as much of a precision drive as a chain or gear drive, and the same care and attention be devoted to insuring three-plane alignment of the set-up, the belts are called upon only to transmit the required horsepower, and should reach maximum service life. Shafts of driver and driven units should be parallel and the center distance the same at both ends of the shafts; sheaves must be accurately centered and properly set on the shafts, and the center lines of individual V's on driver and driven pulleys should coincide. Such a drive setting insures (assuming new, standard sheaves) that each belt of the drive, whether two or a dozen be used to transmit the power, will be of the same length, and will travel exactly as far as does its neighbor with each revolution of the driving pulley. With such a setup, and using factory-matched belts, slipping in the sheave grooves is reduced to a minimum, and consequent wear of the side wall or gripping area practically eliminated.

Installing belts on such a drive calls first for shortening the center distances—by moving one or both units on their foundations—so that the belts can be *laid* in place. Usual recommendation of drive layout is to provide one fifth the adjustment travel toward the other sheave, four fifths in the opposite direction being used to take up belt slack. When the belts are all laid in the grooves of the fixed sheave, varying amounts of slack or sag will be apparent over the span of belt between the two pulleys. It is fatal to proper belt service simply to tighten the drive when this condition exists.

Time spent in adjusting the tension on all the belts to give uniform initial pull on the driving side will distribute the load evenly across the drive, and insure equal wear on all the unts. Since the V-belt cannot slip around the groove in either sheave to adjust itself to the tension in adjacent belts, some maintenance men adopt the practice of blocking the belts in the grooves of the larger or fixed pulley so there can be no slip or shift while checking tensioning. A piece of 2x4 timber, notched to fit over the pulley and apply pressure against the belts, may be held in place with a jack or wedges, and afford a fixed point from which the tensioning may be checked.

Then, taking each belt in turn at the other sheave, the upper span is pulled tight and laid into the sheave groove, being patted or forced into the groove to prevent loss of tension. The slack on the opposite side of the belt should hold this tension unchanged, once the belt is placed. When this operation has been performed on each belt in turn across the drive, the tops of the tight sides should lie in one plane, and should have uniform resistance against vertical deflection.

When the belts have all been placed so as to have apparent uniform tension, and while the one sheave is still blocked with the belt-retaining device, the drive should be adjusted to take up the slack existing in the lower parts of the belts. Since one sheave is free to revolve as this adjustment is being made, all belts should retain their initial tautness. Then, removing the retainer, all belts should show uniform sag under a specified loading.

One check for this before putting a drive into service may be made by laying a straightedge across the drive, and hooking a weight on each belt in turn. Measurement of the deflection will afford accurate indication of the accuracy of the initial tensioning. Should one or more belts show appreciable variation (one used specifies 1/16 inch per foot of span under loading with 10-pound weight on C section belt) the belt or belts showing excessive sag should be readjusted and the variations ironed out before putting power on the drive.

A simple method of insuring belt-tension equaliza-

tion has been worked out by one drilling contractor for use on his drilling-rig drives which gives uniform belt loading and requires less time than the weight-check described above.

The line through the centers of the driver and driven shafts is extended to the rims of the sheaves, and a narrow line scribed or painted across the units parallel to the shafts. The distance between these pairs of lines is therefore the same, top and bottom. The V-belts are likewise marked accurately into halves, with lines across the outer or flat surface so that the distance between them is the same, measured on either portion.

The inner belt of the drive is then laid in place, slack having first been provided by moving the adjustable pulley toward the other to permit this to be done, one mark on the belt being so placed as to coincide with the scribing on the fixed pulley. The other belt mark is aligned with the corresponding mark on the movable pulley, and the other belts then laid in place with the corresponding pairs of belt marks aligned with the pulley guide scribings. This method insures the same amount of belt being applied between marks, with the result that when the drive is tightened the slack is uniformly distributed.

On some drives, to prevent possible shifting of belts as subsequent units are put in place, the adjustable sheave is rotated so as to bring the upper side of the drive approximately taut and flat, and the shaft then blocked so that the unit cannot revolve and return slack to the tight side. Subsequent belts are then laid on and tightened by hand until the midway division marks coincide with those on the sheaves, this putting the same tension in all belts successively. Success of this method lies in the blocking of sheaves so they cannot turn and thus feed back slack, and in the proper settling of the arc of contact of each V-belt with its corresponding sheave groove.

An approximate method of equalizing belt tensions is used by one company, employing V-belt drives on all motor-driven pumping units. An old lawnmower is the adjusting tool; the mower being reversed under the drive so that the ball-bearing wooden roller may be brought up against the under side of the drive by pressing down on the handle. The drive is then adjusted so as to introduce extra slack in the belts, the roller used as idler, and the belt which is tightest, and thus running ahead of its neighbors, is thereby overloaded and made to slip in the grooves until the load is divided fairly evenly. Weight-checks of belts for tension after tightening the drive again show that this temporary application of an idler will compensate for most of the slack in drives using D or E section belts, and will work even better on C or smaller sections.

Need for Tensioning

Because many V-belt drives operate over long periods with considerable sag in the slack side, it is sometimes difficult to get operators to maintain proper belt tension, especially on drives with rapidly changing characteristics or heavy shock or impulse in the driven unit. Unless the drive is properly tensioned, so that the shock is transmitted directly to the driving unit, the belts are subjected to excessive longitudinal snap or stress, and may break even as a loose string may be snapped under sudden jerk when greater force, applied gradually, is easily sustained.

Proper Installation and Care

DO AND DON'T

Do not allow oil, grease or gasoline to come in contact with belts. Avoid exposing belts to sunlight and excessively hot or cold weather. Insure proper sized pulleys for drive. Too small pulleys shorten belt life. Provide take-up facilities. The initial setting should allow 1/5 motion toward driven unit, 4/5 for belt take-up.

Avoid heavy overloads. Add one or more belts to initial set-up if loading is increased.

Don't leave tools or other objects where they may fall into and damage belts.

Avoid abrasion against nearby objects. Slight shaft misalignment may set up destructive side-sway and intermittent contact.

Do not force belt onto sheave with tools of any kind. Slack off on take-up and *lay* belt in grooves.

Work belts around grooves until all the slack is on one side of the drive, and then tighten take-up to secure desired tension.

Use sufficient number of correct-sized belts to handle maximum load. Check to insure sheaves being over accepted minimum diameters for belt size and type used.

Design new drives to call for standard size and length of V-belt with adequate adjustment for stretch.

Prevent V-belts from bottoming in grooves. Bottom friction sets up destructive heat, greatly shortening belt life.

Do not use belt dressing. If belt slips, clean with rag moistened with high-test gasoline (clear, not Ethyl) and tighten drive slightly.

See that all sheave grooves are clean, free from burrs or nicks and excessive wear. Replace sheaves and check alignment periodically.

On failure of first belt in drive, renew throughout. Save other worn belts for replacements as second set shows signs of excessive wear.

Before starting drive first time, check: (1) pulley alignment; (2) bearings for oil; (3) drive clearances. Adjust so that at full load only slight bow or sag appears on slack side.

Vertical drives, extremely short-center installations and drives for pulsating loads where no flywheel can smooth peaks must be operated more tightly than others.

Check for odor of hot rubber. If this persists after first few minutes of operation, drive should be checked throughout for cause and difficulty corrected.

Belts should be stored uncoiled; preferably hung over forms of minimum pulley diameter or larger, and in a cool, dark and *dry* place. Do not hang spare belts on nails or loop over pipes or single board suports, and do not tie together tightly with cord or wire.

Protect against acid fumes, smoke and dust.

If belts break with abrupt section, almost as though chopped with an ax, the drive should be checked for sudden impulses, and the tension adjusted tighter than would be the case were even torque being transmitted.

Tension should be applied or the drive adjusted until slip is eliminated. This can be checked best by taking the speeds of driver and driven shafts and verifying against computed speeds from pitch circle diameters. When but little slip is indicated by this method, a very slight change in shaft distances by adjustment of movable unit should be made. Too much change at this point will overstress the belts and result in premature failure.

Following the placing of the new drive and the initial tension adjustment, additional adjustment will be required after a brief running-in period. On drives in continuous operation with even torque, 48 hours is probably sufficient time to elapse before checking. During this interval the relatively soft outer surface of the rubber, bloom from the vulcanizing, dust and other material loosely adhering to the belt walls will have worn off, permitting the unit to seat slightly deeper in the sheave groove than initially, and thus introducing excess slack. Unless new belts are adjusted thus after a brief running-in period, burning, slipping and other damage is apt to impair the belt and greatly shorten belt life.

Old Sheaves

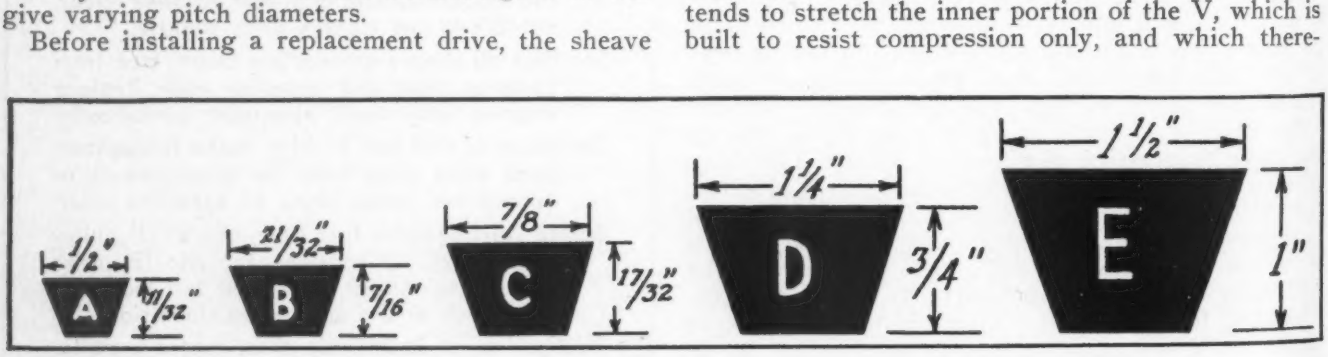
On a new drive, sheave grooves and belt cross-sections are usually properly mated, and correct contact areas are thus assured. When placing new belts on old sheaves, however, it is not safe to assume that conditions are uniform. One or more grooves may be worn excessively, one side of the casting may have been finer grained than the other—sometimes the case when sheaves are cast in job foundries and adequate precautions are not taken to insure uniformity—and the wear in the different grooves will give varying pitch diameters.

Before installing a replacement drive, the sheave grooves should be checked with a template or jig to determine: (1) depth; (2) straightness of groove side walls; (3) angularity of sides; (4) possible adherence of bits of rubber to the groove walls, causing scuffing or pulling of belts. If the grooves do not all show uniform pitch circles, as indicated by the level which the gauge takes in the grooves, it is readily apparent that the various belts are running at different speeds, and that only by slipping of some belts can the entire drive rotate at a given speed. Such a condition is frequently detected on a drive where initial installation did not include equalization of belt tension, or where the two shafts or sheaves are not exactly in line.

Where excessive sheave wear is found, the relative scarcity of belt material over sheaves should call for sheave replacement whenever possible. If replacement is not feasible, care should be exercised in having the sheave turned to proper groove form. On a large sheave, removal of even the relatively small amount of metal necessary to true the grooves may so reduce the pitch diameter of the unit as to exceed the capacity of the belt adjustment provided on the driving unit.

Large sheaves can be built up by metallizing, welding or brazing, or, if the sheave be large enough, the grooves may be partially filled and then turned to give bottom contact only and thus to transform the unit from V-v to V-flat drive. This is especially applicable when the reduction is of the order of 5-1 or greater, and the center distances between shafts is not appreciably greater than the diameter of the larger sheave.[1]

Only when the sheave must be turned down beyond the adjusting limits of the normal drive should a tightener or idler pulley be used. The use of the idler outside the drive introduces backbend of greater or less intensity into the belt, throws compressive stress into that portion of the belt designed and fabricated to sustain stretch only, and in like manner tends to stretch the inner portion of the V, which is built to resist compression only, and which there-



Speed of Small Sheave R.P.M.	HORSEPOWER													
	½	1	2	3	5	7½	10	15	20	30	50	75	100	150 & Over
4000														
3500														
3000														
2500														
2000		A												
1750														
1500														
1250														
1000														
900							B							
800														
700									C			D		E
600														
500														
400														
300														
200														
100														

Typical V-belt cross sections in standard width and thicknesses. Table shows application of each belt size to transmit tabulated horsepower at specified speed of small sheave. If division of drive horsepower by indicated power of certain belt leaves fraction over, another belt should be added to drive. Further overbelting, as advocated by M.V.B.D.A., should also be included if possible to extend life of drive.

TABLE 1

Factors for Belt Horsepower under different applications.

APPLICATIONS	ELECTRIC MOTORS										ENGINES		
	A. C.								D. C.				
	Squirrel Cage			Wound Rotor (Slip-Ring)	Synchronous		Single Phase				Gas and Diesel		
	Normal Torque Line Start	Normal Torque Compensator Start	High Torque		Normal Torque	High Torque	Repulsion and Split Phase	Capacitor	Shunt Wound	Compound Wound	4 or More Cyl. Above 700 Rpm.	Steam	Line Shafts and Clutch Starting
Compressors	1.4	1.4	....	1.5	1.5	....	1.2	1.2	1.2	....	1.2	....	....
Generators and Exciters	1.2	....	....	....	....	....	....	....	1.2	....	2.0	1.4	1.4
Line Shafts	1.4	1.4	....	1.4	1.4	2.0	1.4	1.4	1.4	1.4	1.6	1.6	1.6
Machine Tools	1.2	....	....	1.4	....	....	1.2	1.2	1.2	1.2	....	....	....
Fans and Blowers	1.6	1.6	2.0	2.0	2.0	2.0	....	....	1.4	....	1.6	1.5	1.5
Pumps, Centrifugal	1.4	1.4	1.4	1.6	1.6	1.8	1.2	1.2	1.2	....	2.0	2.0	....
Pumps	....	....	....	....	....	....	....	....	....	....	....	....	....
Units (Ind.)	....	....	....	....	....	....	....	....	....	....	....	....	....

Showing the factor by which the indicated horsepower of the drive should be multiplied before dividing by the indicated horsepower per belt to provide for excess loading through individual drive characteristics. Thus a unit requiring 200 horsepower to operate maximum should have 200 x 1.8 or 360 horsepower in the V-belt drive if from high-speed diesel or gas engine.

fore is built up of fabric or cord plies without sufficient rubber interposed to absorb the reverse flexing demanded by the idler.

Belt Guards

Any V-belt drive should be guarded, both as protection against accidents to operating personnel, and to prevent the damage of the drive through objects falling on it or becoming entangled with the belts and carried over the sheaves. Sunlight, heat, dust and oil are all enemies of the rubber in the belts, and should be excluded whenever possible. The provision of a proper guard should be considered a part of the drive installation, and the guard maintained at full effectiveness to insure drive efficiency.

Care must be exercised when installing a guard to provide proper ventilation. A drive totally enclosed cannot dissipate the heat generated by contact between belt and groove walls, and the cumulative effect gives a temperature rise which soon injures belts, softens the binder, and if not corrected, results in drive failure. The normal V-belt will stand operating temperatures up to 140° F., and special belts, designed and compounded for high-temperature operation, may be run at temperatures of 170 to 200° F., without injury. It should be borne in mind, however, that temperatures in excess of 100° F. hasten oxidation of the rubber and thus tend to accelerate deterioration.

Rough check of the temperature of a drive may be obtained by holding the hand against either sheave immediately after shutting down the drive. If no heat is radiated or conducted from the driver or driven mechanism, the sheave should not feel more than moderately warm. If the sheave feels hot, it is evidence that the temperature is well above safe operating values, and the drive should be corrected. Where the drive is from an internal-combustion engine, and the jacket water temperature can be determined, it is relatively easy to compare the heat of the sheave with that of the engine jacket, and thus to determine the amount of excess heat to which the drive is being subjected.

Guards should provide ventilation. If the guard encloses the drive and is open toward the motor on electric drives, care should be exercised to see that the drive is not on the exhaust side of the motor ventilating system, or the guard will tend to trap the hot, dry air from the motor around the belts, thus aggravating the heating effect. Where this condition cannot be avoided, the guard should fit closely around the shaft on the motor side, and should be open only where the danger of forced hot draft is not present.

If, for protection against external objects, both ends of the drive must be closely enclosed, either the bottom of the guard should be left off, or adequate louvres set in the sides. One drilling contractor insures ventilation for his compounding drives by welding a 3-foot stack of 6-inch pipe atop the high end of the guard, with a 45-degree elbow at its top to divert rain and possible falling objects. The natural draft up this low stack is sufficient to insure fresh, cool air being drawn in at the bottom of the drive case.

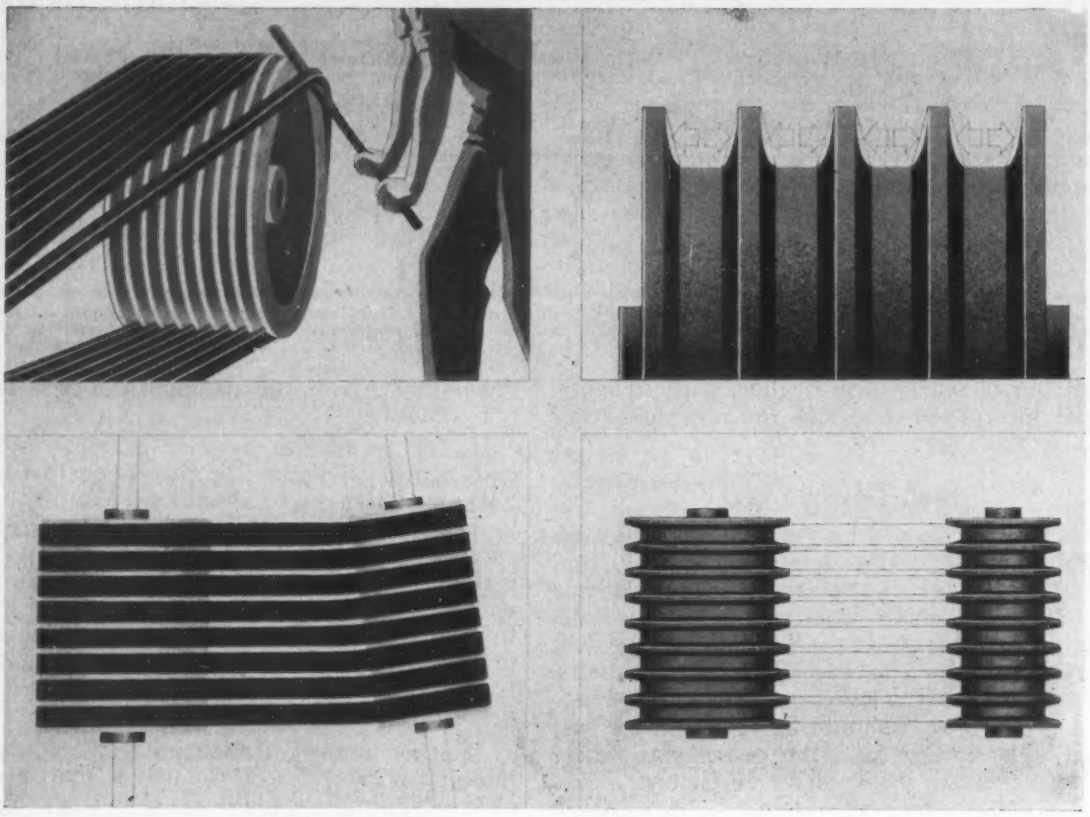
Another method of insuring drive ventilation is to mount a narrow fan on the driver shaft alongside the sheave, a simple paddle-wheel fan setting up an air current which, if directed by the guard, will carry off much excess heat as it finds its way through louvres or apertures in the guard.

Metal is a better material for guards than wood, the use of ordinary corrugated roofing for sides being ample for normal protective purposes, and offering considerable radiating surface for the dissipation of drive heat. If carried on sucker-rod or pipe brackets, with two or more longitudinal braces, this same material is amply strong to protect the drive against any impact save one severe enough to crush even a heavy structure.

Where the drive is initially adequate, but eventually shows high replacement demand, check of the total load frequently brings to light the fact that the initial loading has been increased, and sometimes more than doubled, by the addition of additional units, or in the case of wells, by the drop in fluid level as a field approaches depletion.

Even where no overloading is present, but the drive is being operated at full computed horsepower, statistics developed from tests run by the engineering research bureau of the Multiple V-Belt Drive Association[2] show that, if 10 belts of a given cross-section will fill the normal requirements for a certain drive, adding 1 belt will increase the life of all the belts by 40 percent, and that the use of 2 extra belts, or a 20 percent overbelting of the drive, will give double the life of the drive as originally designed. Likewise, removal of 1 belt from the initial set-up will result in the failure of the remaining 9 after an operating life of only 65 percent that expected from the 10. If the initial set-up be but 5 belts, removal of one will result in cutting the drive life to but 40 percent of that originally planned. These figures show the wastefulness of the usual oil-field practice of continu-

V-Belt Abuse Illustrated



Prying the belt on tends to break down the compression section, introducing a weak spot which imposes shock on the cords and calls for early replacement. Top right shows groove wear on old drive. Attempt to use new belts with this sheave would quickly break down side walls or permit bottom friction and heat damage. Lower left shows side wear between groove and belt when shafts are not properly aligned. Lower right shows how in properly aligned drive belts carry drive loading only.

ing to operate the remaining portion of a drive after the failure of one belt. Even if the remaining belts do not fail by breakage before the full complement is again restored, the stretch and overstress imposed on the belts will greatly shorten their useful life.

Due to the overstressing imposed on one new belt replacing one which has failed from an old set, it is frequently best practice to continue to operate the drive one belt short, rather than attempt to compensate for the overloading by one new unit. Since the old belts run lower in the grooves than new ones, the one replacement will ride high, travel faster, and carry much more than its pro rata share of the load. Cord rupture will probably relieve the belt of its overload after a short period of operating thus leaving the drive in effect one short, and thus illustrating the advisability of running in this condition rather than adding a *new* replacement.

Where belts are available, an entire drive should be replaced as soon as one unit fails. If this is done, the old belts should not be discarded, but kept as possible replacement units for other old drives of equal or lighter demand characteristics. This is especially advisable for belts used to drive pumping units, where many premature failures are encountered due to abuse of the belts in storage, handling, or installation.

One company, having more than 200 V-belt drives on its pumping units in one area, has set up certain tests and standards for checking belts removed to permit installation of complete units. In the central warehouse a standard sheave is bolted to a wall, high enough to allow the maximum belt to clear the floor when hung over it. A small sheave, likewise of the proper cross section for the belt being checked, is provided with a hook slung from a short cross shaft so that the sheave can be set into the lower loop of the belt and a standard weight placed on the hook. A scale, set into the wall and calibrated to allow for both sheave diameters, permits the reading of the exact belt length from a pointer carried on the adjustable sheave shaft. The belt is then tagged to show its exact length under slight—and uniform—loading, and belts of equal length are collected into replacement sets which are found to give greatly extended life over haphazard replacement by belts chosen at random without previous checking.

This same company subjects any belts which show suspicious elongation to a check which detects internal breakdown, cord rupture, ply separation, and other failure which is not visible, or tangible, on the surface. The belt is run over a 6-inch flat pulley, while at the same time a spring-loaded pulley is held against the outside of the bend. A pantagraph pointer on the bearing arm of this pulley magnifies any variation in pulley position, and thus indicates irregu-

larities in the belt cross secton. Thus a rupture in any bank of cord plies would result in excess compression of the belt under the pressure of the loaded pulley, and the incipient failure would be indicated. Likewise, slippage or distortion of one or more of the plies in the fabric envelope of the belt would cause a hump or bunch which also would be shown by pulley arm movement. Belts which show abnormalities under this test are discarded or sent to scrap, as being too near ultimate failure to justify saving. Cutting of a number of belts at the points indicating trouble on the device bore out its accuracy, and thus enabled the company to eliminate double servicing of drives by preventing the attempt at using unserviceable but apparently sound belts.

Belt Repair

While it is theoretically possible to cut out a worn or damaged section from a V-belt and to vulcanize in a repair, the difficulty of obtaining a perfect match between spliced cross section and the original belt is so great as to rule such an expedient out except in extreme emergency. The ends of the splice, no matter how expertly made, are apt to strike each sheave with an impact which, though slight, is cumulative in its effect at breaking down the unit. Even were the splicing such as to leave no shoulder or lap, the difficulty of matching original flexibility and stretch in the vulcanized repair is sufficient to rate possibility of success very low.

If a broken V-belt must be spliced with a metallic fastener, many users believe it advisable to cut the belt again exactly opposite the break, and then to use two splice members instead of one. In this manner they feel that the eccentricity of the drive introduced by the metallic element is counterbalanced and that the effect of centrifugal force through concentration of weight at the splice is equalized all around the drive.

In a class with attempted repair, insofar as its applicability to oil-field drives is concerned, falls the use of any type of belt dressing in a mistaken notion that such a procedure will increase the power transmitted by a given belt, or that such an expedient will take the place of proper tensioning through center distance adjustments.

Dressing applied to the belts will make them tend to follow the groove on the smaller pulley past the point of tangency with the pitch circle of the driving unit. This introduces back bend in the belt, accelerating breakdown, and also subjects the relatively light protection on the sides of the belt to transverse pulling or tearing. Eventually such operation will result in loosening of patches of the sidewall material or "hide" of the belt, with consequent irregular running and exposure of the interior to the effect of water and oil.

Even V-belts compounded with a cover of oil-resisting rubber or natural elastics practically unaffected by oils should be protected against oil drip. Even if the oil is unable to attack the coating of the belt, causing swelling, loosening and eventual flak-

Belt tightener on this drive on an oil-field power is set within the belts and applies tension and bending of the same order as those from driver and driven sheaves. Extreme accuracy of belt manufacture to obtain uniform lengths is shown by lack of vibration in lower belts at full speed and under maximum load.

ing off in the case of rubber, it lowers the coefficient of friction between the belt and sheave groove. This groove is the result of long and painstaking experimentation to determine the angle which will give maximum grip with minimum jamming. Such a groove, lubricated with oil or even a film of water, permits the belt to pull deeper into the groove and then, when the lubricating film has been squeezed out, it tends to jam and cause cover separation or cord failure.

Belt Storage

Instances where spare V-belts are carried in the back of maintenance gang pick-up trucks, there to vie with shovels, wrenches and odd-lot pipe nipples for space, are now few and far between. Difficulty of obtaining replacements, coupled with home-office publicity stressing proper belt protection, now insures the belts being kept in the warehouse until actually needed on the drive. It is in the storage of such units pending need that many companies are finding how inadequate were former methods.

No longer are belts hung over big spikes driven into the warehouse wall, or at best hung across a bracket of sucker rod or pipe. Where there is not space for a form or rack with diameter equal to or greater than minimum acceptable pulley size for the given belt cross section, shelf room is found which will permit the belts to be laid out flat, not coiled. The usual coil, with the belt closely wound and then tied or wired across the coils, tends to force the outer edge of the belt into the sidewall at each point of contact, resulting in deformation if the storage be extended, and subsequent breakage of the nicks and bosses formed, with ultimate belt failure at the weak spot thus started.

Perhaps even more serious in its effect on ultimate belt life is the practice of laying the belt across a bracket or rack sideways, so that the two ends sag and cause a permanent set in the belt which, when placed on a drive, will result in excessive side wear as the curved spots attempt to crowd through the sheave grooves.

Belt storage to obtain greatest service life should be clean, dry, cool, dark or at least out of range of any direct sunlight, and away from possible acid, exhaust or gas fumes.

Experiments have been conducted looking to the possible further delaying of rubber oxidation through the use of some of the rubber paints on replacement belts. Although this is believed effective to prevent oxidation, the paint causes trouble when the belt is put into service, both by slightly enlarging the cross-sectional area of the belt and thus forcing it to ride high in the grooves, and by the frictional heat of belt operation tending to cause the paint to flake off and adhere to the sheave grooves, in turn bringing about sidewall failure and surface breakdown of the unit.

Other companies store spare belts on wide sheets of heavy paper, using sheets of paper between belts, and laying boards carefully around outside of the pile to keep out dust, fumes and light.

Capacity to stretch and return to its original shape is one of the most valuable characteristics of rubber, and is one most valuable when incorporated in V-belts. It must be remembered "that a rubber article which is kept under constant tension is much more susceptible to deterioration than the same rubber article at rest."[3] Thus if a V-belt drive is to be out of service over long periods, as on pumping installations at wells which are still making production by natural flow, V-belt life is extended and probable running time extended by slacking off on the drive adjusting screws so as to relieve the drive of that tension which must be in it if it is to transmit its rated horsepower without slip. One company, making this adjustment to conserve belt life, hangs a red placard over the motor switch calling for drive adjustment before attempting to pump.

Even better belt protection is secured, of course, if the belts be removed and stored properly against the time of probable use.

Where wells require infrequent agitation to restore natural flow, practice now tends to the removal of the V-belts on pumping drives at those units, and the carrying in the service truck of a single set of matched belts for use when power must be applied to the well.

If mildew is observed on any canvas objects, such as fire hose, stored in the company warehouse, all V-belts should be examined and wiped clear of any growth. Even though rubber-impregnated, the canvas forming the envelope for the cord carcass of the belt can be attacked by mildew and the ensuing rot break down the waterproofing afforded by the rubber, permitting the tension cords to be affected and the entire structure weakened to a point where it will speedily fail when subjected to the loads it is supposed to carry safely.

Even though protective measures may cost several times the initial price of the V-belt in time and labor, protection of the small available stocks to insure uninterrupted operation of the country's oil industry will pay big dividends in production when oil is needed. Conservation of V-belts on the lease and in the pump house alone may easily mark the difference between the oil that is ammunition when it is needed and the "too little and too late" which doomed many men and ships in the early days of the war. To save V-belts, use them carefully, and avoid the twin abuses of neglect and overloading.

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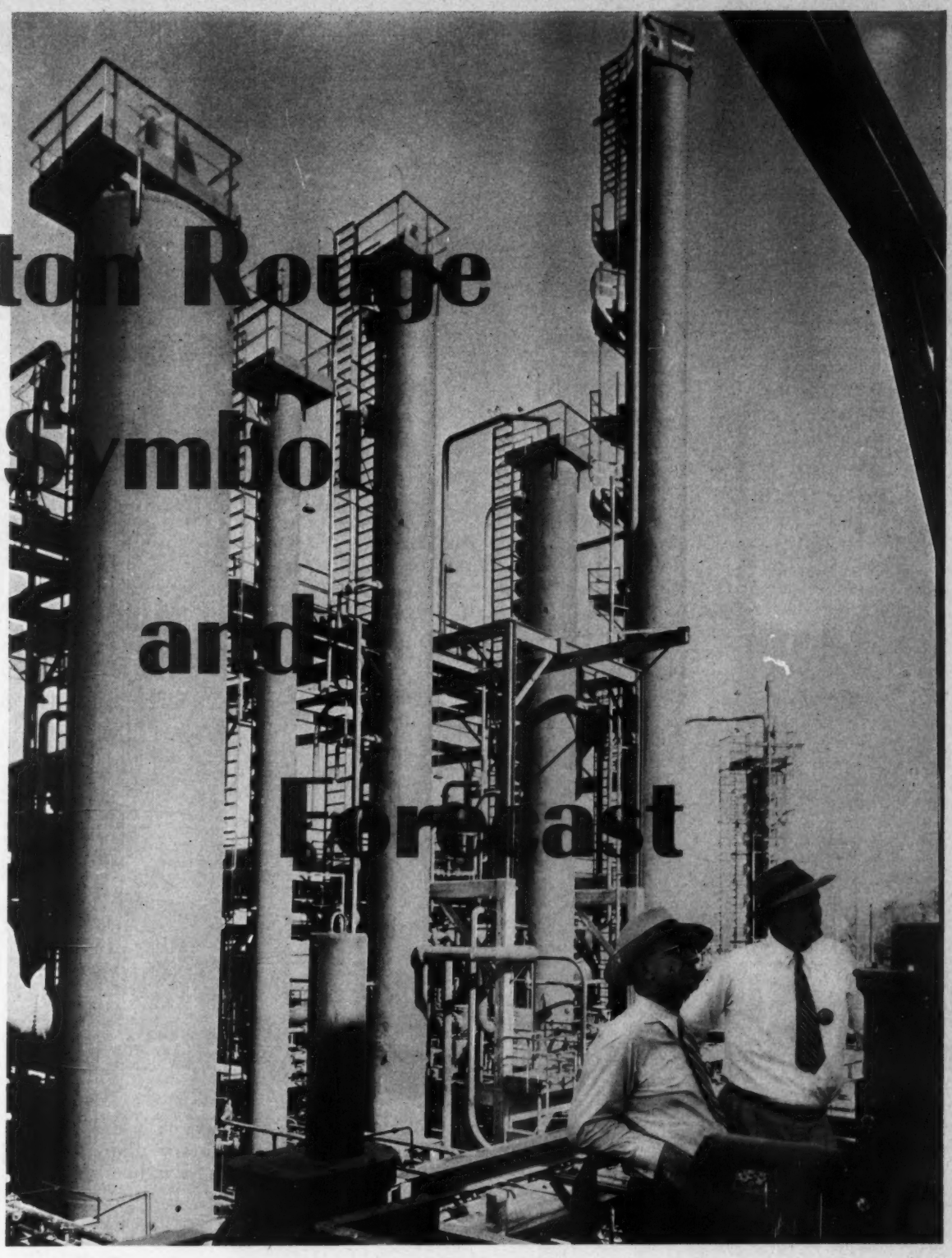
[1] F. L. Ives, "Power," December, 1940.

[2] "23 Ways to Conserve Life of Multiple V-Belt Drives," Multiple V-Belt Drive Association bulletin.

[3] Wm. S. Richardson, "Factory," February, 1942.

Baton Rouge Symbol and Forecast



M. W. BOYER AND M. J. RATHBONE, vice president and president of Standard Oil Company of Louisiana, look things over as the fifth and largest butadiene unit at the Baton Rouge plant goes on stream. Completion of this unit rounded out commitments between the company and the government in butadiene production, the first such accomplishment in the petroleum industry.

A third of the output of the Baton Rouge plant is converted into critical petroleum products for the war program.

SINCE Standard Oil Company of Louisiana was the first in petroleum circles to complete its construction commitments for butadiene manufacture, Baton Rouge became the logical starting point for an inspection trip of military and civilian officials from Washington. Previously Robert P. Patterson, Under Secretary of War, and William M. Jeffers, Rubber Director, had agreed that going into the field to see for themselves would help in solving differences between synthetic rubber and aviation gasoline equipment priorities.

Accordingly the company and its parent organization, Standard Oil Company (New Jersey) set aside May 30 and 31 for playing host to Washington officials as well as news writers and technical-trade-paper editors.

Although scheduled as an opportunity for learning what one company and one refining plant have contributed to the program for critical

CORE OF THE PRODUCTION of critical war products from petroleum at Baton Rouge is the fluid catalyst unit. The one at the right has been in operation since May, 1940, after almost two years under construction. Design changes plus difficulty in getting materials contributed to the long construction period. On one of its early runs, 43 days, however, it had throughput of 140 percent of design capacity.

The units under construction are fundamentally identical with the first one, whose operation permitted design changes to save steel, instruments and other critical materials.

The fluid catalyst process gets its name because its catalyst, a solid of fine mesh, flows in operation. It is charged with a distillate from pipe-still operation. Its principal product is base stock for 100 octane aviation gasoline. Slight changes in temperature and other operation conditions have given it a high yield of gases, which are converted into butadiene, toluene, ethylene, ethyl and isopropyl alcohols and feed for the alkylation units. More than 30 units are operating or under construction.

petroleum products for war, the two days amounted to proof of what the whole petroleum refining industry shortly will provide for the prosecution of global war as well as an indication of the eventual expansion of petroleum refining into one of the top ranking of chemical processing industries.

Baton Rouge is both symbol and forecast.

More than a third of its daily charge of 120,000 barrels is finished as a product essential to military operations. This means that given the equipment and the time petroleum refining could bolster the war program at least to the extent of a third of the nation's refining capacity, because the processes are operating. To gain that status, petroleum refining has come to be chemical processing, a status it will maintain in a world at peace.

Baton Rouge holds its place in petroleum refining for several basic reasons. It is the largest of the field laboratories of Standard Oil Development Company. Since laboratory developments so frequently go into test tube and finally pilot plant operation at Baton Rouge, the plant of necessity has developed a personnel for carrying processes into commercial scale. M. J. Rathbone dwelt on this in his background explanation of processes before the first plant visit of news writers when he explained:

"On account of the diversified activities carried on at this plant it has

become essential to build up a large technical organization as well as develop an operating personnel capable of taking hold of new and strange plants and rapidly placing them in successful operation. This combination of highly diversified operations and personnel who are accustomed to working with new and unusual operations, contributed materially to the ability of this refinery to carry forward the extensive war program as rapidly as has been the case."

This evolution of process growth had concrete evidence in the fluid catalyst process, which had one unit operating at Baton Rouge, two nearing completion, while the pilot plant of the process is still standing. The place of investigation was summed up by F. A. Howard, president of Standard Oil Development Company, this way:

"The processes you have seen in operation here represented 8,500,000 man hours of research and development."

Among those who came from Washington were Robert P. Patterson, Under Secretary of War; James V. Forrestal, Under Secretary of the Navy; William M. Jeffers, Rubber Director; Ralph K. Davies, Deputy Petroleum Administrator; Bruce K. Brown, Assistant Deputy Administrator of PAW; Bradley Dewey, Deputy Rubber Director, and J. W. Livingston, vice president of Rubber Reserve Company.

If Patterson and Jeffers had had serious differences in Washington, they were not brought to Baton Rouge. Their joint statement on the trip was:

"The trip we are now making is for the purpose of seeing actual equipment that has been built, to see whether, where and how the programs actually conflict and, if we find bottlenecks, to eliminate them promptly and objectively so that a truly integrated program will move forward with a speed which will break our enemies at the earliest possible date."

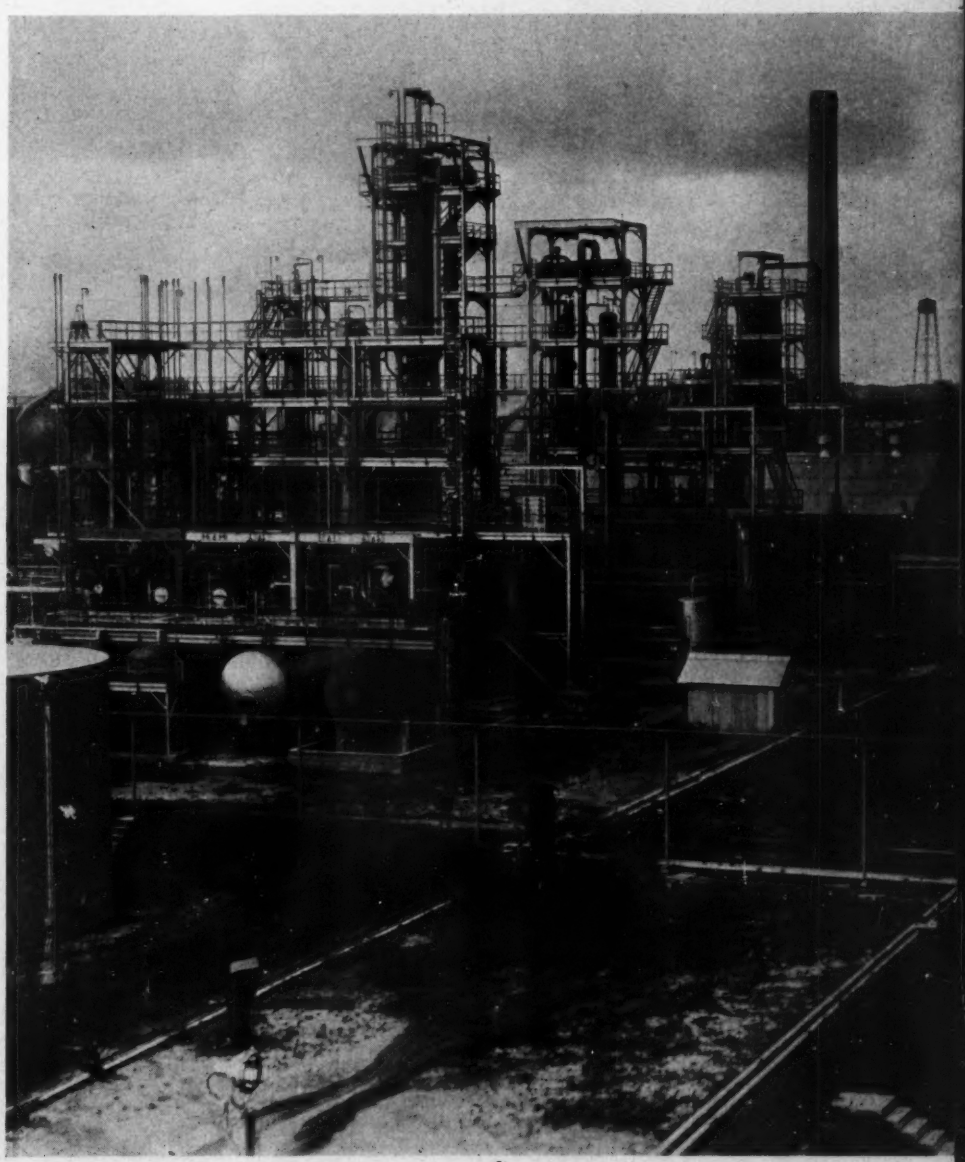
What they saw at Baton Rouge was an integrated program, wherein both aviation gasoline and synthetic-rubber ingredients come through identical processing previous to final processing. Especially designated for inspection were:

The fluid-catalyst process, one unit operating and two nearing completion;

Five butadiene plants, two of the thermal-cracking process, two of the later butylene-dehydration-process and an example of refinery conversion (the quickie method);

The high-pressure petroleum-hydrogenation plant;
The toluene plant, still under construction;
The alkylation units;
Butyl rubber manufacture;
Buna-N (Perbunan) rubber manufacture.

Of these only toluene and alkylation are not de-

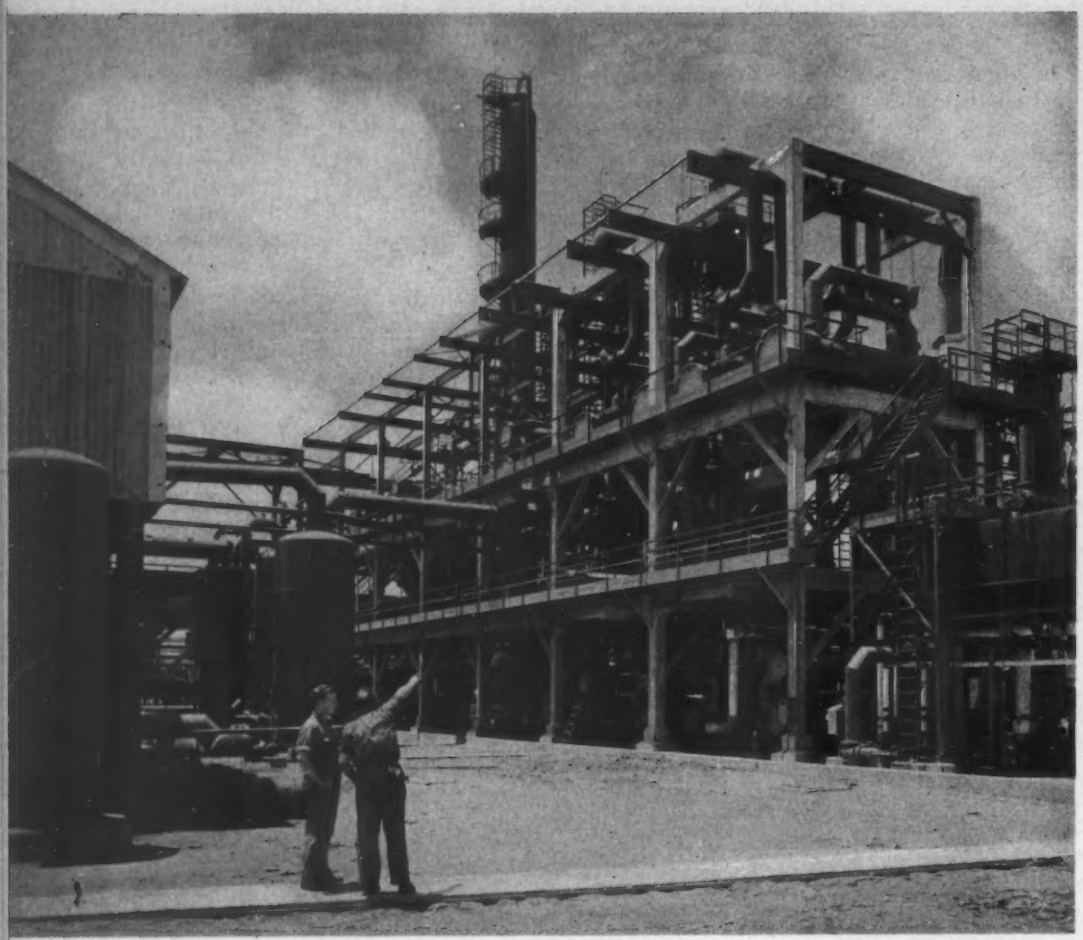


FIRST LARGE SCALE PRODUCTION of butadiene from petroleum was in this thermal-cracking plant, completed in January, 1942. A year later a second thermal cracking unit was completed. The first one was built to provide butadiene for increasing the capacity of the Buna N (Perbunan) copolymerization plant, still being operated at Baton Rouge.

Before the second plant was finished, the synthetic rubber program of the nation was taking shape and laboratories as well as pilot plants were in need of raw materials for research and experimentation, so this plant contributed to that phase of the program. Both plants were financed by the company.

Operation of these plants is by high-temperature cracking of oil, with the result that several gaseous products are formed, one being butadiene. Other gases are usable in aviation gasoline blending agents, tetraethyl lead and explosives. Although not as efficient as the newer method of producing butadiene by dehydrogenation of butylene, operation of these plants was the first in which the synthetic-rubber and aviation-gasoline programs were drawn together.

What these plants accomplished was the basis of the recommendation of the Baruch committee that a substantial part of the butadiene from petroleum be provided by conversion of existing thermal cracking equipment to higher temperature cracking. Although this program subsequently was curtailed, one of these conversions is the third butadiene unit at Baton Rouge.



LARGEST OF THE BUTADIENE UNITS at Baton Rouge is the butylene dehydrogenation plant, which completed the commitments between Standard Oil Company of Louisiana and the government. It had been in operation less than a month when its operation was thus described, "on its very first run meeting designed capacity and quality specifications."

Its charge is butylene from fluid catalyst cracking. Dehydrogenation consists of removal of two hydrogen atoms from each butylene molecule. Details of operation are not made public.

Previous to completion of this unit a small dehydrogenation plant had been put in operation in February by remodeling some existing construction built for Ethyl Corporation, one of whose plants adjoins the property of Standard Oil Company of Louisiana. This small unit, in addition to contributing 10 tons of butadiene daily, will be operated as a pilot plant for the whole synthetic rubber program.

The five plants at Baton Rouge furnish all butadiene requirements for the adjacent rubber plant of Copolymer Corporation, a combination of several of the smaller rubber companies, which is operating a government plant for making Buna S synthetic rubber. Excess butadiene is shipped to other rubber plants.

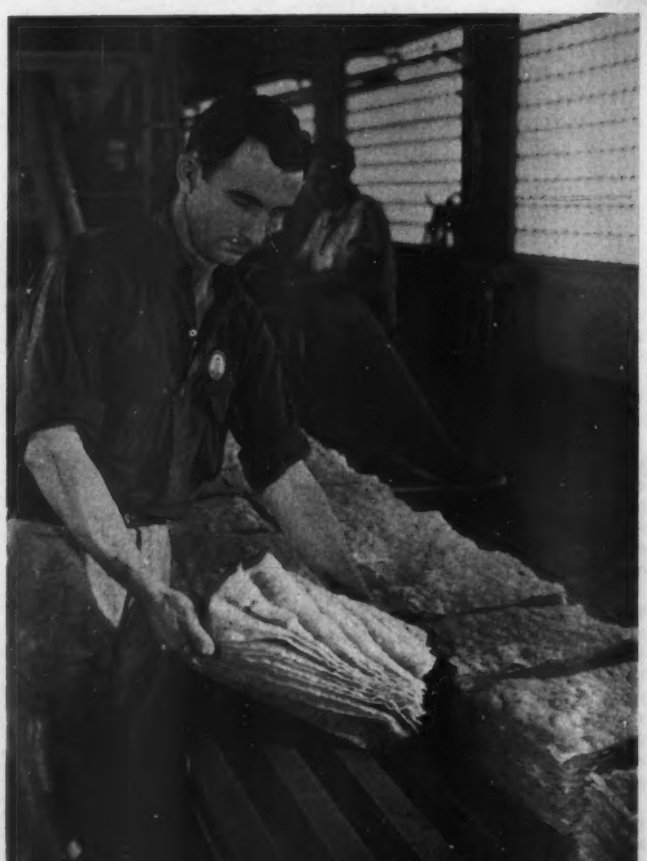
Two of the butadiene plants were financed by Standard Oil Company of Louisiana, one is owned by Defense Plant Corporation and two jointly by the company and the government.

velopments of Standard Oil Company (New Jersey) and its subsidiaries.

In addition, the trip included an inspection of the plant of Copolymer Corporation, built by Defense Plant Corporation for rubber synthesis and operated by a corporation formed by several of the independent rubber companies.

Standard Oil Company of Louisiana had its thirty-fourth birthday April 13, 1943. When the plant was started on the east bank of the Mississippi river in 1909 a cotton plantation of 213 acres was selected, as its site. Now the plant covers more than 1000 acres, while another 1000 is required for tankage.

Along with growing up in capacity it has grown up in personnel, since nearly 8000 workers are required for the processing and other activities of processing more than 100,000 barrels of crude oil daily. These employes work an average of 51.35 hours per week and average weekly earnings are $62.00. The average hourly earning is $1.20 and the income for a month is $267. Its 1900 salaried workers have average income of $288 per month.



IN THE DEVELOPMENT of a synthetic rubber program following the fall of Singapore the petroleum industry was charged with providing part of the butadiene, some styrene, the chemical industry with providing soap acids and other chemicals, leaving the rubber industry to put these together as Buna rubbers.

The copolymerization plants are standardized units, whose design and operation came out of the experience at Baton Rouge. A small copolymerization plant has been operating there since April, 1941. Its first capacity was 1,600 tons per year. With the completion of the first thermal butadiene unit, capacity was increased to 3,600 tons per year.

It is still operating, being presently restricted to making Buna N (Perbunan) a special synthetic, one of whose uses is for lining aviation fuel tanks to make them bullet proof. Buna N synthetic rubber is a combination of butadiene, acrylonitrile and other chemicals. Buna S rubber requires styrene instead of acrylonitrile. Reactions are so nearly identical, however, that the equipment can be used for either.

Through the pay-roll-deduction plan employes of this company have bought more than $1,500,000 in war bonds.

Although 200 miles from the Gulf of Mexico, the plant has deep harbor facilities. Its products are shipped by tanker, river and canal barges, pipe lines, tank cars and trucks. It is farthest inland of the plants along the Gulf of Mexico.

Chronology of the expansion of special processes at Baton Rouge is:

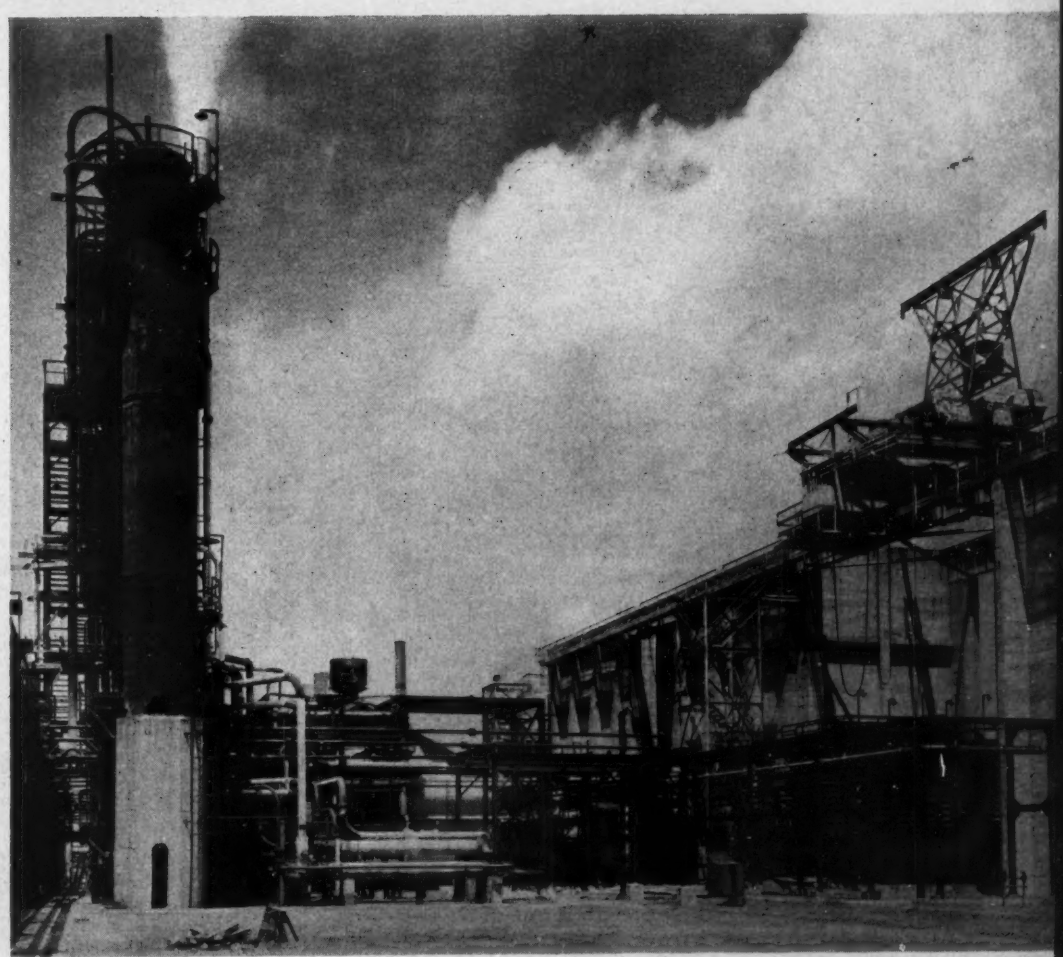
Hydrogenation. The high-pressure petroleum-hydrogenation plant was completed in 1931. It has served to manufacture lubricating oil, 100-octane gasoline and now processes special cuts from 45 other refining plants into blending agent for 100-octane gasoline.

Buna Rubber. A small copolymerization plant for Buna-N (Perbuna) manufacture has been operating since April, 1941. Its first capacity was 1600 tons per year. Expansion to 3600 tons, its present capacity,

BUTYL is the only synthetic rubber made wholly from petroleum and manufactured by the petroleum industry. One unit is now operating at Baton Rouge, a second is under construction and other plants are being built by Humble Oil & Refining Company and Imperial Oil, Ltd. Total capacity, financed by the government, will be 75,000 tons per year.

It is made by reacting isobutylene, a cracking-operation gas, and isoprene, at the extreme temperature of minus 150° F. It is a specialty product, which so far does not match Buna S for tire purposes, whose history and qualities have been summed up:

"Butyl is a synthetic rubber developed as a laboratory product by Standard Oil Company (N. J.) scientists in 1937 and improved by continuous research since that time so that it now plays a small but important part in the government rubber program. Butyl has not yet matched the tire making characteristics of Buna S. It can, however, be used to make inner tubes superior to those made from Buna S or natural rubber. Some of its important properties are resistance to oxidation and the action of acids and high impermeability to gases."



OLDEST of the special products units at Baton Rouge is the high pressure petroleum hydrogenation plant, completed in 1931. Hydrogenation, adding hydrogen, gained its early favor because of its promise of converting more of crude oil into motor fuel. When this hydro plant was completed the East Texas oil field had for the time removed immediate concern over crude oil shortage.

One of its early uses was in making hydrogenated lubricating oils. Then it was put into the production of aviation gasoline. Normally it can produce both base stocks as well as blending agents for 100 octane aviation gasoline. Development of catalytic cracking soon solved the need for base stock, leaving high octane blending agents the more urgent need. The plant then was turned to processing products from more than 40 refining plants into high-octane blending agent.

came in 1942. Methods for making this rubber are so closely identical with Buna-S synthesis that experience of this small plant was the basis for the design of the units, financed by the government, for synthesis of the whole Buna-S program.

Butadiene. First butadiene was made at Baton Rouge in January, 1942, in order to have a supply for the enlarged capacity of the Buna-N synthesis plant. This was a thermal-cracking unit and a similar one of larger capacity was completed in January, 1943. Much of the output of this second plant went to laboratories and pilot plants, where the larger synthetic-rubber industry was being fashioned following the fall of Singapore.

One refinery conversion (quickie) butadiene unit is operating at Baton Rouge. Four thermal oil-cracking units were removed from gasoline manufacture January 1, 1943, and three months later were making butadiene. Operation is based on knowledge gained from operation of the two thermal-cracking butadiene units.

Of the two butylene-hydrogenation units at Baton Rouge, one is of pilot-plant capacity, 10 tons daily, completed in February, 1943, by remodeling some equipment previously built for another purpose for The Ethyl Corporation, one of whose plants is nearby. It served for pilot-plant study for determining operating methods for the larger units now going on stream over the nation and will continue in that service.

The first and largest of the butadiene units went on stream in May, 1943.

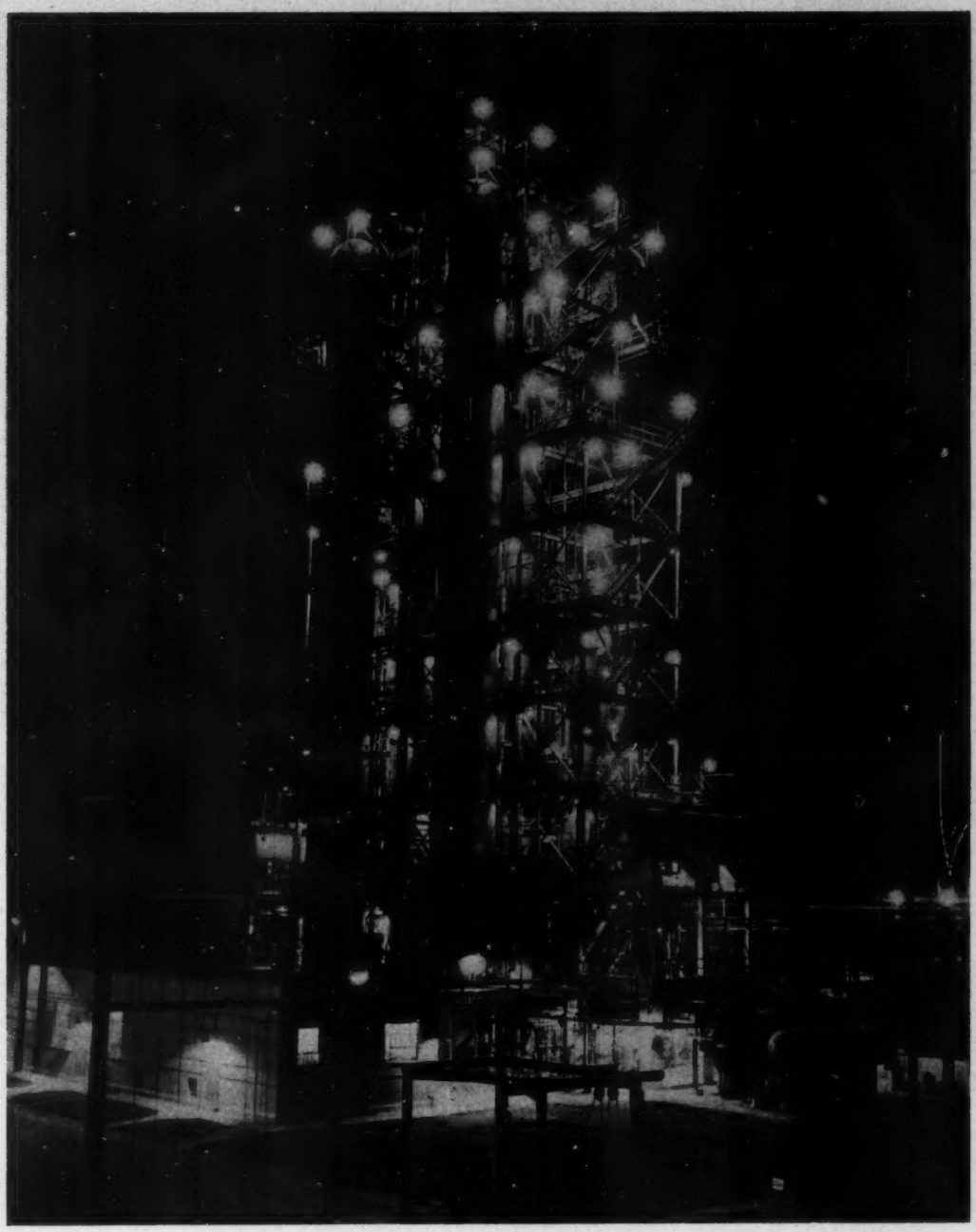
Most of the butadiene made at Baton Rouge will go to the adjacent rubber synthesis plant of Copolymer Corporation.

Butyl Rubber. Butyl rubber is wholly a petroleum product, which will be manufactured at two plants in the United States and one in Canada. The first of the manufacturing unit was put in operation at Baton Rouge in May, 1943.

Alkylation. This process, not strictly a development of Standard Oil Company (New Jersey) subsidiaries, has been operating at Baton Rouge since 1942.

Toluene. This hydrocarbon ingredient for TNT will be made at Baton Rouge upon completion of a plant now under construction.

ALKYLATION, the combining of a paraffin and an olefin, brought to refining the assurance of high-octane blending agent for aviation gasoline. The three towers here represent as many sulphuric acid alkylation plants, which are part of the aviation gasoline equipment at Baton Rouge. The alkylation process and that for making toluene are not sole developments of Standard Oil Company (N. J.) and its subsidiaries.



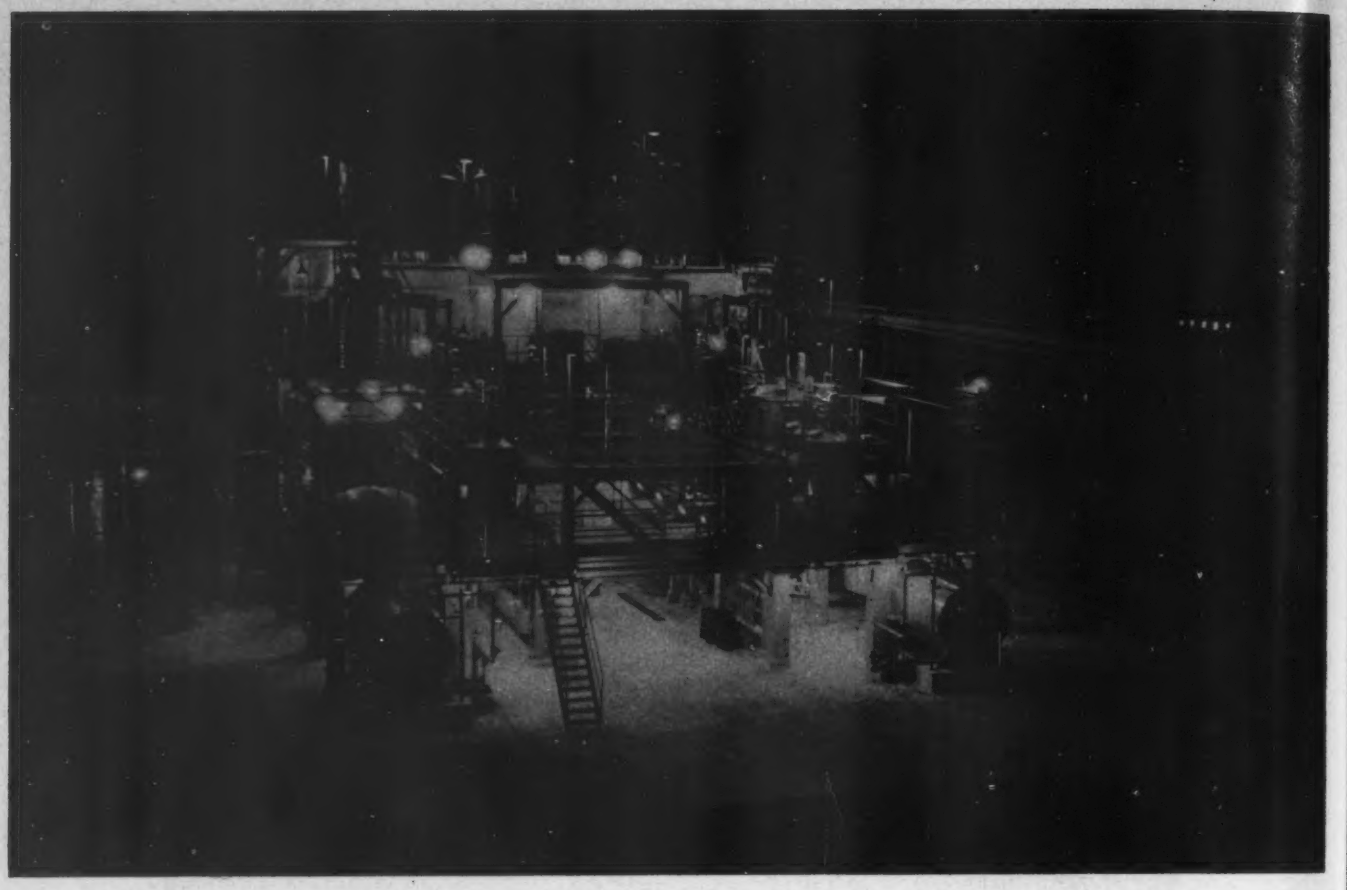
Distillation Unit

Petroleum Refining Processes Adapted to Styrene Manufacture

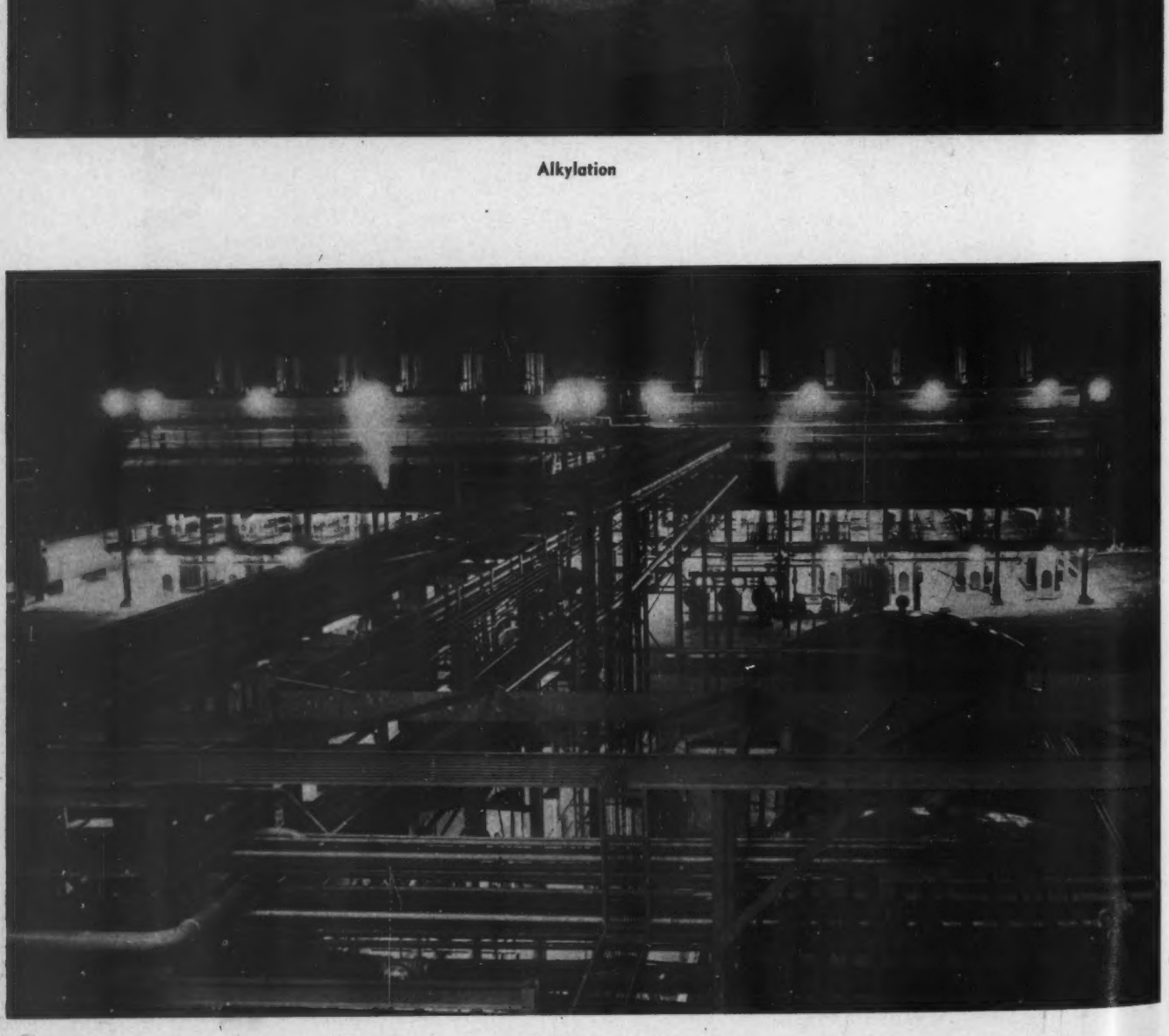
MANUFACTURE of styrene, second hydrocarbon group of Buna rubber, with propane as one of the raw materials has been established with completion of a plant by Monsanto Chemical Company at Texas City, Texas. Like butadiene, styrene may come from several sources. Until synthetic rubber stimulated demand it was a product of coke-oven distillation.

Now it will be produced at Texas City and other places by adaptation of processes from petroleum refining, thermal cracking, alkylation and dehydrogenation. Styrene is a combination of ethlyene and benzol.

Operation of the plant of Monsanto Chemical Company calls for the cracking of propane to produce



Alkylation



Dehydrogenation

ethylene, then alkylation of ethylene and benzol to form ethylbenzene, followed by dehydrogenation of ethylbenzene to form styrene. This brief outline of processing is all censorship restrictions will permit.

The first styrene shipped from this new plant, March 10, 1943, was made from ethylene and benzol from outside sources. The plant was completed just one week less than a year from the date of starting construction. First design called for annual production of 3000 tons. This was successively stepped first to 6400 tons, 10,000 tons, 20,000 tons, 40,000 tons and finally 50,000 tons, which will be the rate of production before the end of the year.

Some construction details made public by the operating company are:

Metal requirement, 13,250 tons of steel and iron, 290 tons of copper and alloys, 160 tons of alloy steel, 16 tons of nickel alloys.

The major unit for distillation is comparable with a 20-story building in height.

The water-pumping unit can handle 35,000 gallons per minute.

The project was financed with government funds, cost $17,000,000, and is owned by Rubber Reserve Company.

Twenty percent of the plant is underground.

The lighting arrangement is such that the crew of an airplane going over at night cannot detect the location, although an observer on the ground would be viewing a brilliant spectacle. The plant can be blacked out in one minute and still remain in operation.

The following information was released shortly after the plant was visited by William M. Jeffers, Rubber Director, and associates:

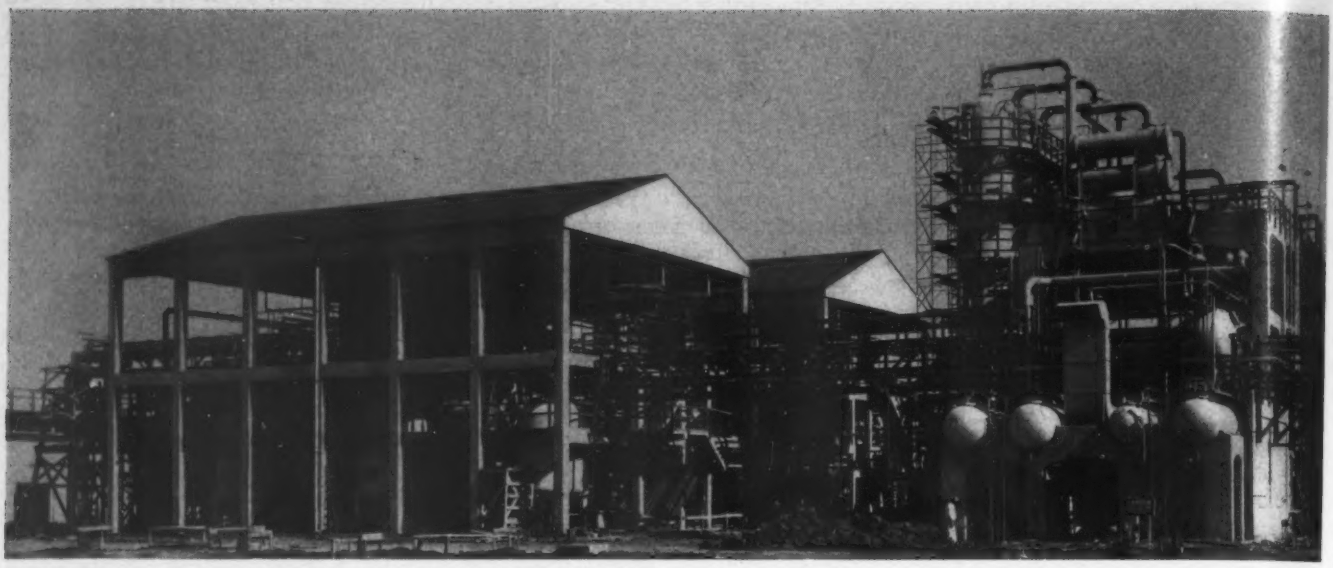
"Styrene is described by chemists as an aromatic hydrocarbon compound having a double bond. This double bond is the key to its usefulness in both plastics and in synthetic rubber. The double bond on each molecule of styrene enables individual molecules of the compound to be linked together into long chains. The process of hooking together is called polymerization and radically changes the appearance and physical and chemical properties of the material. When styrene alone is polymerized, it is changed from a clear-white liquid to a hard, dense glass-like substance. When styrene and butadiene are polymerized together, the product is a rubber-like material known as Buna S.

"Production of styrene at the plant is based on two raw materials—propane, a petroleum fraction, and benzene, a by-product of coke ovens. In the first step, propane is cracked to supply ethylene gas. This cracking is somewhat similar to methods used in the petroleum refining industry. Ethylene gas and benzene are then combined in the second step to form ethylbenzene. The process by which this is carried out is known as alkylation.

"Styrene differs from ethylbenzene by having two less atoms of hydrogen. Ethylbenzene is converted to styrene by removal of the extra hydrogen in a dehydrogenation process.

"In designing and in operating the plant, Monsanto Chemical Company has been able to draw not only on its own technical resources but on the background and research of every other company in the field. Through Rubber Reserve Company, an industry technical committee provides for the free interchange of information. Through this system several companies, normally highly competitive in peacetime, work together for the war effort. As a result, the design of the Texas City plant, although substantially a Monsanto project, uses some processes and methods developed by other companies."

Control of all processing is by one instrument board, housed in the distillation unit.



Excess butadiene and styrene are recovered and returned to storage for recycling in the operation of a rubber synthesis plant. Above the unit at the right includes the distillation equipment for this recovery. At the left are the reactors where all chemicals are agitated under controlled conditions. Open type housing is typical of construction in the southern climate.

Copolymerization Is the Process of Building a Rubber Like Substance Under Controlled Synthesis

MANUFACTURE of the first synthetic rubber in Texas, June 28, was celebrated as "American Made Rubber Day," by proclamation of Governor Coke R. Stevenson, who was one of the speakers at programs at Goose Creek and Houston. The plant, built by Goodyear Tire & Rubber Company for Defense Plant Corporation, will be operated by General Tire & Rubber Company and General Latex & Chemical Company. Butadiene is being provided by Humble Oil & Refining Company, Baytown, and styrene by Monsanto Chemical Company, Texas City.

Copolymerization of Buna rubber is no function of petroleum refining. The rubber industry will operate these plants, all of which are adjacent to butadiene and Styrene plants.

Butadiene and styrene are combined with soap solution, brine, sulphuric acid and a catalyst in reaction chambers, where the combination is stirred continuously. This operation is of the batch type. Combination of the ingredients is arrested at a predetermined stage. Then it is successively washed, dried, rolled into sheets and finally pressed into bales for shipment to rubber plants, where it is used after the fashion of natural rubber latex in making finished materials.

Butyl rubber consists of two petroleum products, isobutylene and isoprene and is made by the petroleum industry.

In the picture on this page the chemical-mixing unit and the recovery equipment are at the right, while the reaction chambers are in the building at the left. The process is carried out with a surplus of both butadiene and styrene present. The excess is recovered and the two products go back to storage for later use.

This unit of 30,000 long tons annual capacity will produce latex equal to the output of a rubber plantation of 100,000 acres.

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★ *A reprint of a paper presented to the Tenth Mid-Year meeting of the American Petroleum Institute, by R. A. Wilkins, Director of Revere Research, entitled "Corrosion of Copper and Copper-Base Tubing in Oil Refinery Heat-Transfer Equipment" will be gladly sent on request.*

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DIGEST OF UNITED STATES PATENTS

On Isomerization of Hydrocarbons

Compiled by Heinz Heinemann

U.S.P. 2,268,401. Isomerization Process. Ch. N. Kimberlin, Jr., to Standard Oil Development Company.

Several processes for the isomerization of normal to iso-paraffins are known, in which Friedel-Crafts type catalysts and activators such as hydrogen halide are used. While most of the hydrogen halide can be recovered from the effluent of the reaction zone, small losses do invariably occur. When recycling the hydrogen halide in mixture with fresh normal-paraffins, it is proposed to add small amounts of alkyl halides like carbon-tetrachloride. The alkyl halides react with hydrocarbons to form hydrogen halide which replaces losses of hydrogen halide.

U.S.P. 2,271,043. Isomerization of Hydrocarbons. A. J. van Peski to Shell Development Company.

An isomerization such as the production of iso-pentane from normal-pentane or other isomerizations of saturated hydrocarbons containing 4 or 5 C-atoms is effected by means of an aluminum halide catalyst under between 0.08 and 33 atmospheres of hydrogen, the partial pressure of the hydrogen being sufficient substantially to repress side reactions, but insufficient substantially to repress the isomerization reaction.

U.S.P. 2,277,512. Catalyst. Martin de Simo and F. M. McMillan to Shell Development Company.

It has been found that the catalytic activity of aluminum halides is considerably increased when they are used in combination with certain forms of alumina. The effect of the alumina when in combination with an anhydrous aluminum halide is unique, very pronounced and not approached by other carriers. The promoting action is not general to all of the many forms of alumina, but is confined to crystalline alumina alpha monohydrate, "activated alumina," prepared by partial dehydration of crystalline alpha alumina trihydrate. The anhydrous aluminum halide may be combined with the carrier by mixing the powdered materials and pelleting them, by soaking granules of the carrier in non-aqueous solutions of aluminum halide or in other ways.

U.S.P. 2,278,934. Process and Catalyst for Conversion of N-Paraffins. M. W. Lee to Union Oil Company of California.

The isomerization of normal-paraffins and particularly of n-butane is carried out by aluminum halides and particullarly by aluminum bromide in the liquid state and at temperatures of more than 125° and below cracking temperature and under sufficient pressure to maintain a liquid phase. It has been discovered that the isomerization of n-paraffin may be greatly increased as to yields by conducting the reaction in the presence of a catalyst containing carbon and particularly activated carbon. It is not believed that the carbon acts merely as a distender or carrier agent, because yields are much lower when using natural or treated clays instead of carbon. Aluminum bromide in a quantity equal to 25 percent of the weight of hydrocarbons treated together with 18 to 19 percent of carbon is used at 212° F., 220 pounds pressure for a period of 4 hours. Conversion yields up to 74 percent are obtained.

U.S.P. 2,780,710. Isomerization Process. Ch. S. Lynch to Standard Oil Development Company. C.A. 36, 5483.

A process is employed which involves bringing at least one normal-paraffin containing at least 4 C-atoms per molecule into contact with a metal halide isomerization catalyst of the Friedel-Crafts type under isomerization conditions in a step-wise process, carrying out the reaction in at least two stages maintaining a temperature gradient between the stages, the last stage being maintained below the temperature employed in at least one other stage and correlating the temperature of any particular stage with the length of time the feed is subjected to that temperature so as to avoid substantial cracking of the paraffins and products obtained while effecting substantial isomerization of the n-paraffin.

U.S.P. 2,280,748. Isomerization of N-Paraffins. Van B. Calhoun to Standard Oil Development Company.

It has been found that superior results may be obtained by using free halogens, especially chlorine or bromine as activators for Friedel-Crafts catalysts in the isomerization reaction. The yields of branch-chain hydrocarbons are considerably greater than those obtained by the use of known activators such as hydrogen halides. These activators have a further advantage over hydrogen halide in the fact that they promote the formation of the branch-chain isomers of a given hydrocarbon with less tendency to form hydrocarbons of a lower or higher number of C-atoms in the molecule. The new class of activators are particularly effective when used with aluminum halide catalysts. The amount of activator required varies with the catalyst, its age and the temperature and other conditions, but ordinarilly the amount is from 0.5 to 5 percent of the feed stock treated. A temperature range of from 30 to 400° may be used and the process can be operated in both liquid and vapor phase.

U.S.P. 2,281,924. Executing Reactions with the Aid of Fugitive Catalysts. M. de Simo and F. M. McMillan to Shell Development Company.

In reactions with catalysts containing anhydrous $AlCl_3$ such as the isomerization of hydrocarbons, the losses of $AlCl_3$ by volatilization from the reaction zone under reaction conditions are considerable. The aluminum chloride condenses in cooler parts, plugging up equipment. According to the invention, escape of $AlCl_3$ is substantially avoided by employing a suitable solid adsorptive material which is unsaturated with respect to the $AlCl_3$ in close association with the catalyst. Adsorptive alumina is a suitable material. The carrier-supported catalyst and the solid adsorptive alumina which is unsaturated with respect to $AlCl_3$ are either mixed prior to charging the reaction chamber or are separately placed in the reactor in such a manner that the reactants pass first through a bed of catalyst and then through a bed of adsorptive alumina.

U.S.P. 2,283,852. Production of Iso-paraffins. Gustav Egloff to Universal Oil Products Company.

A process for the production of low-boiling iso-paraffins is described, comprising subjecting a combined feed formed in a manner hereinafter described to the action of anhydrous $AlCl_3$, a minor amount of hyrdogen chloride and hydrogen containing gases in a primary reaction zone, simultaneously subjecting a second combined feed formed in a manner hereinafter described to the action of anhydrous $AlCl_3$, a minor amount of hydrogen chloride and hydrogen containing gases in a second reaction zone, commingling the conversion products from the two reaction zones and subjecting the mixture to a separation step to separate a fraction containing iso-butane and iso-pentane, a low-boiling gasoline and a higher-boiling naphtha, commingling the aforesaid low-boiling gasoline charge stock to form the primary combined feed hereinbefore set forth and commingling the naphtha with a naphtha charge stock to form the second combined feed hereinbefore set forth.

U.S.P. 2,288,477. Production of Iso-Butane. Ch. W. Montgomery to Gulf Research and Development Company.

Normal-butane, substantially free of olefins is maintained in contact, eventually in the presence of hydrogen halide, with a metal halide catalyst and preferably with aluminum halide at a temperature below the critical temperature of the n-butane and preferably under pressure sufficient to maintain the n-butane in a liquid state. Iso-butane is produced without substantial cracking and without tar formation on the catalyst. Aluminum halide is used in amounts of 0.5 to 10 mol percent.

U.S.P. 2,291,376. Isomerizing Hydrocarbons. H. A. Cheney to Shell Development Company.

To overcome difficulties encountered in using customary aluminum halide catalysts for isomerization reactions, a great many materials were investigated as catalysts, mostly with negative results. Liquid aluminum halide catalysts

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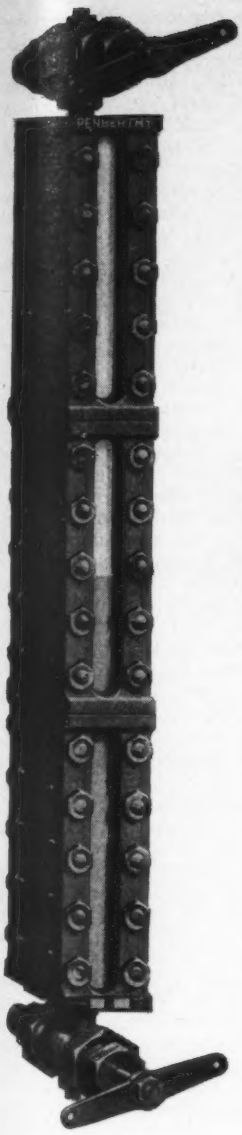

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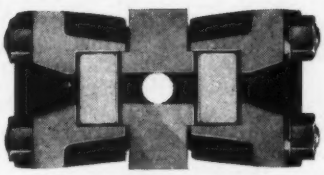

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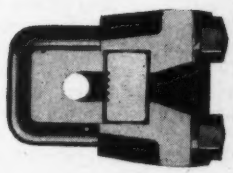

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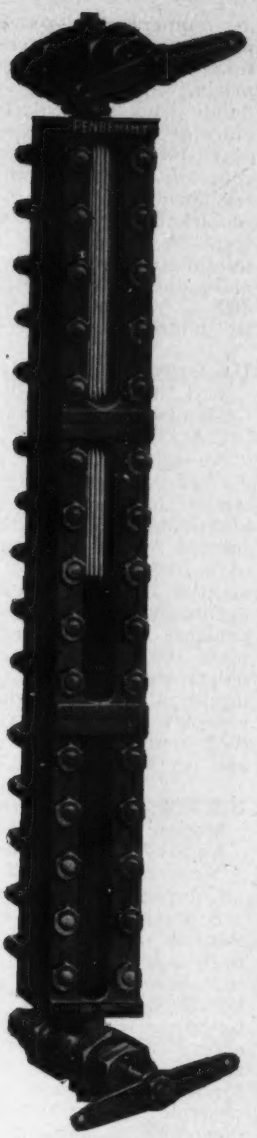

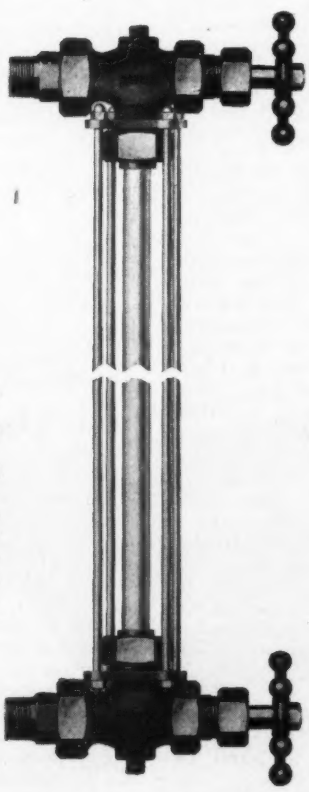

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at temperatures above their melting point are also ineffective. It has been found, however, that fluid melts, comprising a molecular excess of aluminum halide and particularly of aluminum chloride, and a halide of an alkali metal, when promoted by from 0.3 to 25 percent of arsenic trichloride, antimony trichloride or bismuth trichloride are remarkably good isomerization catalysts. A temperature range from the minimum at which the catalyst may be maintained in the liquid phase to about 200° C. can be used. Pressure is of little influence upon the reaction.

U.S.P. 2,293,891. Catalytic Reactivation. B. L. Evering and E. L. d'Ouville to Standard Oil Company (Indiana). C.A. 37, 1257.

An arrangement of apparatus is described and a process is employed which may involve regenerating an aluminum halide hydrocarbon sludge formed, with hydrogen in the presence of a hydrogen halide and in the substantial absence of other regenerating agents, with use of an elevated temperature and pressure adapted to promote the restoration of the aluminum halide sludge to form an active mobile liquid aluminum halide hydrocarbon complex catalyst. HCl may be used with temperatures of 200° to 500° F. and pressures of 40 to 400 atm.

U.S.P. 2,295,977. Process for the Preparation of an Aluminum Chloride Catalyst. S. B. Thomas and F. M. McMillan to Shell Development Company.

A mineral carrier such as activated alumina or diatomaceous earth is partially dehydrated, so that it will contain only a small amount of firmly bound water. Pieces of the thus prepared carrier are soaked in a substantial excess of molten anhydrous aluminum chloride over that adsorbable to the carrier. The excess molten aluminum chloride is then drained off in an atmosphere of aluminum chloride vapors under pressure and the impregnated carrier is cooled to below 190° F. The catalysts may contain as much as 50 percent aluminum chloride. Using a catalyst prepared from activated alumina and aluminum chloride for the isomerization of n-butane to i-butane, an average i-butane content of over 60 percent was obtained during 126 hours of continuous operation.

U.S.P. 2,297,617. Conversion of Hydrocarbon Oils. A. R. Goldsby to The Texas Company.

A combined isomerization and cracking process, using two steps is described. $AlCl_3$ type catalysts are used for the isomerization step. High antiknock motor fuel hydrocarbons are obtained from saturated straight-chain hydrocarbons.

U.S.P. 2,298,931. Process for the Treatment of Hydrocarbons. H. E. Drennan to Phillips Petroleum Company.

The catalyst used consists of copper oxide and a copper salt and is prepared by treating copper oxide with a nonvolatile strong inorganic acid like sulfuric acid or phosphoric acid.

U.S.P. 2,299,716. Process for the Production of Hydroaromatic Hydrocarbons. A. J. van Peski to Shell Development Company.

A naphthenic distillate is subjected to fractional distillation and a fraction is cut which boils up to 75-78° and contains paraffinic hydrocarbons and naphthenic hydrocarbons of non-hydroaromatic character, having substantially equal boiling points. This fraction is treated in the liquid phase at temperatures below 200° with an aluminum chloride-hydrocarbon complex catalyst. Cyclohexane is recovered from the isomerized distillate by fractional distillation.

U.S.P. 2,300,160. Isomerization of Normal-Paraffins. K. C. Laughlin to Standard Oil Development Company.

The hydrocarbons are isomerized by a Friedel-Crafts type catalyst at a temperature of from 30 to 400° F. and preferably 150 to 250° F. in the presence of an activator consisting of about 0.5 to 10 percent of carbon dioxide (based on the weight of hydrocarbons present).

U.S.P. 2,300,235. Isomerization of Paraffins. H. Pines and H. S. Bloch to Universal Oil Products Company.

The isomerization is carried out with an anhydrous $AlCl_3$ catalyst and hydrogen chloride as an activator. The effluent from the reaction zone is separated into an isomerized fraction, unconverted paraffins and a gas mixture containing hydrogen chloride. The last is contacted with a solid adsorbent which will adsorb the hydrogen chloride. The hydrogen chloride is then desorbed from the adsorbent and recycled to the isomerization step.

U.S.P. 2,301,342. Olefin Isomerization. D. Somerford and K. C. Laughlin to Standard Oil Development Company. C.A. 37, 2013.

Non-tertiary-carbon-atom containing mono olefins having at least four C atoms in the molecule are subjected to isomerization conditions (preferably 400 to 1200° F.) in the presence of a catalyst containing oxides of boron and aluminum.

U.S.P. 2,301,615. Treatment of Hydrocarbons. J. A. Chenicek and K. M. Brown to Universal Oil Products Company.

A combination isomerization-alkylation process is described using anhydrous $AlCl_3$ as a catalyst. The n-paraffinic hydrocarbons are charged, respectively recycled to an isomerization zone under isomerization conditions. For n-butane these are 125 to 225° F. and a space velocity of about 0.25. It may be operated as a vapor or liquid-phase process, the former having the advantage that less $AlCl_3$ is lost by vaporization than by dissolving, the latter having the advantage of higher conversions. The isomerization zone is followed by a catalyst pick up zone in which $AlCl_3$ is dissolved in the hydrocarbons prior to entering an alkylation zone in which i-paraffins are alkylated with an added stream of olefins.

U.S.P. 2,306,261. Catalytic Conversions and Catalysts Therefor. C. C. Crawford and W. E. Ross to Shell Development Company.

It has been discovered that aluminum halides such as in particular $AlCl_3$ and $AlBr_3$ react with cyclic olefins to form liquid complex addition compounds which are unexpectedly quite different from those produced from open-chain olefins and are superior to the various liquid complexes hitherto employed. The liquid complex addition compounds formed from aluminum halides and cyclic olefins, unlike those formed from open-chain olefins and aromatic hydrocarbons, are relatively stable and exhibit better activity. It is also considered of great importance that the excellent catalytic activity of these complex compounds is very selective. Thus by the application of these complex compounds, excellent conversions may be obtained while degradation reactions practically do not take place, whereas when using other types of complexes the conversions are either much lower or considerable side-reaction products are formed. The substantial absence of degradation reactions when employing these cyclic olefin complexes is believed to be a factor contributing toward their greater stability. One suitable method of preparation is, e.g., to mix the aluminum halide and cyclic olefin and gently heat the mixture at about 80-110° C. preferably while stirring. The cyclic olefin complex contains about 1 to 2.5 mols of olefins to each mol of $AlCl_3$. Aluminum halide may be used in excess. Isomerization conditions are those commonly used for isomerization reactions.

U.S.P. 2,307,053. Isomerization of Normal-Paraffin. Ch. S. Lynch to Standard Oil Development Company.

Aluminum halides catalysts are best suited for the isomerization of hydrocarbons in the presence of hydrogen halide promoters while fresh. As the catalysts become spent, the tendency to catalyze cracking reactions increases. It has now been found that an isomerization catalyst which has developed a tendency to further cracking reactions can be advantageously used to isomerize hydrocarbons with less C atoms to the molecule than that which they have previously isomerized. It is thus, e.g., possible to use a liquid-phase process, contacting n-pentane with about 100 percent by weight of fresh $AlCl_3$ and about 5 percent by weight of hydrogen chloride at a temperature of 110° F. for about 0.75 hours and obtaining substantial amounts of i-pentane. After 3 hours of use, n-butane is charged to the same batch of catalyst instead of n-pentane under the previously stated conditions and substantial yields of i-butane are obtained.

U.S.P. 2,309,263. Process for the Production of Catalysts. B. S. Thomas to Shell Development Company.

A process for the production of aluminum halide catalysts is described. Inorganic carrier material and preferably adsorptive alumina, containing bound water is heated to a temperature above 140° C. at moderately elevated pressure in a closed vessel with sufficient aluminum halide to react with at least a substantial amount of the bound water, but insufficient to saturate the adsorptive material. A pressure increase is caused by hydrogen halide formation, which is vented above 140° C. to restoration of the original pressure. The reaction is continued until the decomposition of aluminum halide hydrates is completed. The product formed is impregnated with a second portion of aluminum halide in sufficient amount to produce a catalyst con-

TUBE-TURN WELDING FITTINGS—RANGE OF SIZES

Type of Fitting	Description	Standard Weight	Extra Strong	Schedule 160	Double Extra Strong	Light Gauge	
						Nominal Pipe Size	Iron Pipe Size
Elbows	90° Long Radius	½"-24"	¾"-24"	1"-14"	1"-8"	4"-24"	3"-12"
Elbows	90° Short Radius	1"-30"	1½"-30"				
Elbows	45° Long Radius	½"-30"*	¾"-30"*	1"-14"	1"-8"	4"-24"	3"-12"
Returns	180° Long Radius	½"-24"	1"-24"	1"-14"	3"-8"	4"-24"	3"-12"
Returns	180° Short Radius	1"-30"	1½"-30"				
Returns	180° Extra Long Radius	1"-2½"	1"-2½"				
Tees	Straight	½"-24"	½"-24"	1"-12"	1"-8"		
Tees	Reducing Outlet	¾x⅜-24x20	¾x⅜-24x20	¾x⅜-12x18	1x⅜-8x6		
Reducers	Concentric & Eccentric	1x⅜-24x20	1x⅜-24x20		1x¾-8x6		
Caps		¾"-24"	¾"-24"		1"-8"		
Stub Ends	Lap Joint	¾"-24"	¾"-24"				
Nipples	Shaped, 90° to Header	1¼"-12"	1¼"-12"				
Nipples	Shaped, 45° to Header	1¼"-12"	1¼"-12"				
Saddles		2"-24"					
Laterals	Straight	1¼"-24"	1¼"-24"				
Laterals	Reducing	1¼"-24"	1¼"-24"				
Crosses	Straight	¾"-24"	¾"-24"				
Rings	Welding	¾"-12"	¾"-12"				
Sleeves	Welding	2"-24"					

*30" size short radius.

SUPER Tube-Turn 45° long radius elbows, 90° long radius elbows, and 180° long radius returns available in both Standard weight and Extra Strong in sizes from 3" to 12".

Tube-Turn welding fittings and flanges conform to applicable ASA and ASTM Standards. For further details please refer to Tube Turns catalog and data book No. 111.

TUBE-TURN FORGED STEEL FLANGES—RANGE OF SIZES

	150 Lb.	300 Lb.	400 Lb.	600 Lb.	900 Lb.	1500 Lb.	2500 Lb.
Welding Neck	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Slip-On	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Lap Joint	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Threaded	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"	½"-24"	½"-24"
Blind	½"-24"	½"-24"	½"-24"†	½"-24"	½"-24"*	½"-24"	½"-24"
Socket Type	¼"-24"	¼"- 4"		¼"-3½"			
Reducing-threaded or slip-on	¾"-24"	¾"-24"	¾"-24"	¾"-24"	¾"-24"	¾"-12"	¾"-12"
Orifice—threaded		1"-24"	4"-12"	4"-12"	3"-12"	1"-12"	
Orifice—slip-on		1"-24"					
Orifice—welding neck		1"-24"	4"-12"	1"-12"	3"-12"	1"-12"	
Long Welding Neck	1"-24"	1"-24"	1"-10"	1"-10"	1"-10"	1"-10"	

†Dimensions on sizes thru 3½" same as for 600 lb. flanges.
*Dimensions on sizes thru 2½" same as for 1500 lb. flanges.

TUBE-TURN

Welding Fittings and Flanges

The ★ FIRST WELDING FITTINGS 1ST AND STILL THE BEST

TUBE TURNS (INC.) LOUISVILLE, KY. *Branch offices:* New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Houston, Los Angeles. *Distributors in principal cities.*

taining 17 to 23 percent of aluminum halide.

U.S.P. 2,309,986. Motor Fuel and Preparation Thereof. R. F. Ruthruff.

In the preparation of motor fuel the steps are claimed which comprise subjecting a heavy naphtha to destructive isomerization, separating the destructively isomerized product into a relatively low-boiling fraction and a relatively high-boiling fraction having a maximum boiling point lower than the initial boiling point of said heavy naphtha, alkylating said relatively low-boiling fraction and blending the alkylate with the high-boiling fraction. During destructive isomerization the naphtha is treated at 205 to 210° F. with a suitable catalyst (e.g., $AlCl_3$) promoted with water, HCl, CCl_4 or the like. A large proportion of i-butane is obtained.

U.S.P. 2,311,232. Manufacture of Catalyst. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

Catalysts suitable for promoting organic reactions are obtained from anhydrous metal halides and particularly $AlCl_3$ and adsorbent carriers such as charcoal, clays, siliceous materials, etc. The $AlCl_3$ and the carrier are mixed in the desired proportions. In the case of activated carbon equal proportions have been found satisfactory. The mixture is heated at elevated temperatures and under pressure until the chloride has been adsorbed in the pores of the carrier. For this purpose the mixture is placed in a glass-lined vessel, a small amount of hydrogen chloride is added, the vessel is brought to a pressure of approximately 25 atmospheres by introduction of hydrogen and heated to approximately 250° C. for several hours. The product is dry and granular and the $AlCl_3$ has apparently disappeared but is present in the pores of the adsorbent.

U.S.P. 2,311,712. Process for the Preparation of Catalysts. B. S. Thomas to Shell Development Company.

Optimum promoting action of the carrier material in carrier supported $AlCl_3$ catalysts is obtained when very thin films of $AlCl_3$ are deposited on the surface of the carrier by impregnation with $AlCl_3$ vapors. According to the invention the vapor-phase impregnation is effected and superior catalysts are produced under controlled conditions in a continuous or semi-continuous countercurrent process. An adsorptive carrier is passed in the form of fragments or granules in a bed down through a vertically disposed adsorption column maintained at a temperature between 190 and 300° C. Vaporized $AlCl_3$ is entering at the bottom of the column and passed countercurrently to the carrier through the bed. Catalyst is withdrawn from the column below the entrance point of $AlCl_3$ vapors.

U.S.P. 2,311,713. Catalyst and Process for the Preparation Thereof. S. B. Thomas and F. M. McMillan to Shell Development Company.

A process for the production of improved combination $AlCl_3$ catalysts is described which comprises the steps of providing a bed of adsorptive catalyst carrier material containing a small amount of firmly bound water and passing vapors of $AlCl_3$ therethrough. Under suitable conditions the carrier becomes impregnated with from 8 to 28 percent $AlCl_3$, which is deposited on the surface in a thin film. The $AlCl_3$ vapors and the carrier material are maintained at a temperature above the $AlCl_3$ vaporization point during the adsorption step.

U.S.P. 2,313,053. Catalyst and Preparation Thereof. M. de Simo and F. M. McMillan and H. A. Cheney to Shell Development Company.

The preparation of new aluminum halide catalysts is described which are said to be vastly superior due to increased activity, superior mechanical strength and less desintegration during use. $AlCl_3$ and suitable catalyst carrier, such as the various siliceous and/or aluminous materials of natural or synthetic origin, e.g., clay, bauxite, fuller's earth, bentonite, kaoline, Florida earth, kieselguhr, montmorillonite, permutites, etc., which has been preferably, but not necessarily partially dehydrated by heating at 200 to 400° C. are mixed. The mixture is heated while under superatmospheric pressure to a temperature, sufficiently high to melt the $AlCl_3$ (at least 190° C., preferably 200-300° C.) under a pressure of e.g. 40 pounds. Pressures of from 40 to 1000 pounds may be employed. The catalytic mass obtained upon cooling is crushed to desired sizes. The increased catalytic efficiency of these materials is due to the promoting effect of the admixed components. The catalysts are excellently suitable for isomerization, alkylation, polymerization and cracking reactions.

U.S.P. 2,313,054. Catalytic Isomerization of Saturated Hydrocarbons. M. de Simo, F. M. McMillan and H. A. Cheney to Shell Development Company.

The catalysts prepared according to U.S.P. 2,313,053 are used to isomerize saturated hydrocarbons and with special advantage n-butane and n-pentane, methylcyclopentane and dimethylclopentane in the presence of hydrogen halide promoters. Conversion rates up to 64 percent are obtained under isomerization conditions.

U.S.P. 2,313,661. Isomerization and Alkylation of Paraffins. C. W. Montgomery to Gulf Research and Development Company.

A combination isomerization and alkylation process using $AlCl_3$ catalysts and hydrogen halide promoters is described. The reactor consists of a hot zone containing the catalyst and a following cool zone. Isomerization occurs when passing hydrocarbons through the hot zone. Aluminum halide is vaporized and carried over to the cool zone, maintained at a temperature sufficient to condense all aluminum halide but to keep hydrocarbons vaporized. Alkylation occurs in this zone. When the catalyst efficiency of the hot zone is reduced below the desirable, the hot zone is cooled and the cool zone heated and the gas flow reversed.

U.S.P. 2,314,297. Process of Isomerization. C. W. Watson to The Texas Company.

When isomerizing hydrocarbons with aluminum halide catalysts, hydrogen halide is used as a promoter. While the hydrogen halide has previously been mixed with the charge and passed over the catalyst, it is now suggested to introduce the promoter at a plurality of points within the reaction chamber. The concentration of the promoter is regulated to be highest where the concentration of n-paraffins is lowest. Higher conversion rates are thus obtained and rapid spoilage of the catalyst at the entrance zone of the reactor is avoided.

U.S.P. 2,315,197. Method of Preparing Alkylated Hydrocarbons from Normal-Paraffinic Hydrocarbons. A. R. Goldsby and K. Korpi to The Texas Company.

A combination isomerization and alkylation process with recycling of unused n-butane to the isomerization zone is described.

U.S.P. 2,316,247. Isomerization of Paraffins. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

For the isomerization of n-paraffins a composite catalyst is used which consists of substantially anhydrous chlorides of aluminum and zirkonium and a porous adsorbent. The reaction is carried out in the presence of small but definite quantities of hydrogen halide. A conversion of 30 to 60 percent per pass can be obtained. N-butane can be isomerized within the range of 50 to 350° C. under pressure ranging from atmospheric to 200 atmospheres and preferably from 10 to 200 at 125° C. and higher. Increased pressure reduces the volatility of $AlCl_3$ and represses side reactions. Hydrogen halide in quantities of 0.5 to 10 percent by volume of butane is present during the reaction.

U.S.P. 2,316,248. Isomerization of Paraffins. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

Hydrocarbons are isomerized under the conditions of U.S.P. 2,316,247 with a catalyst consisting of the substantially anhydrous chlorides of aluminum and copper and a relatively inert carrier.

U.S.P. 2,316,775. Treatment of Hydrocarbons. G. Egloff to Universal Oil Products Company.

A process is described which comprises subjecting n-butane to contact with vaporized $AlCl_3$ at an isomerization temperature below the sublimation temperature of $AlCl_3$ in the presence of hydrogen chloride to give a reaction product containing a substantial portion of i-butane which is then alkylated with olefins. N-butane is heated to 100 to 350° F. at a pressure ranging from atmospheric to approximately 1000 pounds and commingled with from 0.5 to 20 percent by weight of hydrogen chloride and up to 10 percent by weight of vaporized $AlCl_3$.

U.S.P. 2,317,241. Production of Iso-Butane. W. A. Ackerman and W. S. Bonell to Gulf Research and Development Company.

Aluminum chloride is dispersed in an inert liquid such as carbon disulfide, carbon tetrachloride, ethylbromide, chloroform, etc. The liquid must have a boiling point higher than that of n-butane. A portion of the dispersion is constantly withdrawn from the body thereof and returned to the body of dispersion in a downward path. The temperature of the body of dispersion is high enough to produce a substantial amount of aluminum halide vapor.

TODAY THE MODERN G-MV COMPRESSOR IS PREFERRED FOR:

SYNTHETIC RUBBER
SYNTHETIC AMMONIA
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GAS REFORMING
NATURAL GASOLINE CYCLING
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COMPRESSING AIR AND GASES FOR OTHER VITAL WAR INDUSTRIES

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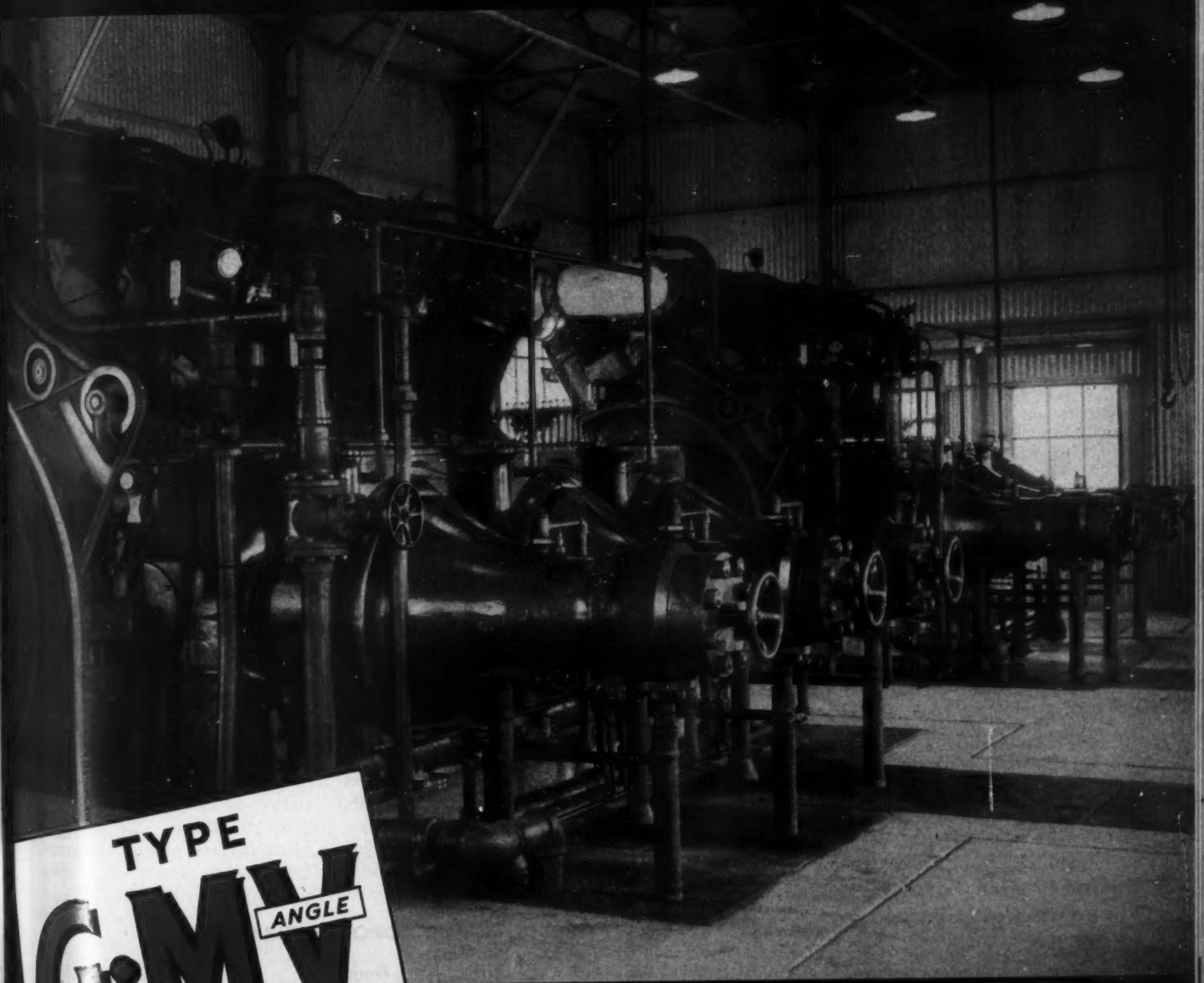


TYPE G-MV ANGLE Compressor

New York Washington Bradford, Pa. Parkersburg, W. Va. Gloucester, Mass.

N-butane is constantly introduced into the dispersion and conducted together with aluminum halide vapor upwards in countercurrent contact with liquid dispersion returning to the main body of dispersion whereby the vapors are cooled sufficiently to condense aluminum halide.

U.S.P. 2,318,225. Production of Iso-Butane. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

A process for producing iso-butane is claimed which comprises subjecting n-butane to the action of an iron halide under conditions and in the presence of an amount of hydrogen halide such that isomerization of n-butane constitutes the principal reaction of the process.

U.S.P. 2,318,226. Production of Iso-Butane. V. N. Ipatieff and H. Pines to Universal Oil Products Company.

A process for producing iso-butane is claimed which comprises subjecting n-butane to the action of boron fluoride in the presence of metallic nickel under conditions and in the presence of an amount of hydrogen halide such that isomerization of n-butane constitutes the principal reaction of the process.

U.S.P. 2,320,293. Conversion of Paraffinic Hydrocarbons. P. Ostergaard to Gulf Oil Company.

A method of rapidly conducting the conversion of paraffinic hydrocarbons into other branched-chain hydrocarbons in the liquid phase and in the presence of a liquid aluminum halide-hydrocarbon catalyst is claimed, which comprises so thoroughly and intimately contacting the hydrocarbon reactant material with the catalyst that a mixture is produced which has substantially no tendency to separate in the zone of reaction and which separates slowly by gravity separation after withdrawal from the zone of reaction, withdrawing such mixture from the zone of reaction and introducing it into a first separating vessel and separating the mixture therein into a liquid layer comprising the major part of the reaction product substantially free from catalyst and a liquid layer comprising catalyst containing substantial amounts of reaction product, separately withdrawing the substantially catalyst-free product and the reaction product-catalyst mixture from said vessel, recylcling the major part of the withdrawn reaction product and catalyst mixture to the zone of reaction, introducing a minor part of the withdrawn reaction product-catalyst mixture into a second separating vessel and therein effecting a substantially complete separation of catalyst and reaction product, and separately withdrawing the substantially catalyst-free reaction product and the thus separated catalyst from said second separating vessel.

Refinery Fire Fatal to Three Ashland Employes

Three men were fatally burned from an explosion and fire at the refining plant of Ashland Oil & Refining Company, Ashland, Kentucky, June 15. Boyd Morgan, general superintendent; Crosby Rodgers, chief maintenance engineer, and Tom Brown, cracking plant operator were the victims.

Synthetic Rubber Program Shaping Up to Assure Capacity Operation This Year

Oil came into national promise as the source of the major part of the synthetic rubber program June 28, which previously had been proclaimed "American Made Rubber Day" by Governor Coke R. Stevenson of Texas. The occasion was the formal opening of the rubber polymerization unit at Baytown, which will be operated by General Tire & Rubber Company and General Latex & Chemical Company. Butadiene for the unit is being made by Humble Oil & Refining Company and styrene is coming from the Texas City plant of Monsanto Chemical Company.

The event, a program at Goose Creek near the plant, a luncheon in Houston and a national radio program in the evening amounted to an announcement that the plants that will contribute to the making of synthetic rubber in the Southwest are nearing completion. By November 1 the area will be producing 351,000 tons of butadiene, 100,000 tons of styrene, 345,000 tons of Buna S rubber latex and 68,000 tons of Butyl rubber.

The full program for the nation amounts to 735,000 tons of Buna S rubber and 75,000 tons of butyl rubber.

Plants in Arkansas, Louisiana and Texas will produce 351,000 tons of butadiene each year, leaving 117,500 tons to be made from oil elsewhere and 220,000 tons from alcohol, a national total of 735,000 tons per year.

Two styrene plants in Texas will use propane as part of their raw material.

Manufacture of Buna S latex at Baytown was the second such event in the Southwest, as a similar plant at Baton Rouge began manufacture in May. Standard Oil Company of Louisiana, Baton Rouge, likewise has completed its butadiene commitments with the government and now has annual capacity of 31,500 tons.

The plants being completed in Texas and adjoining states are a part of the

BUTADIENE MANUFACTURE

TEXAS

Company—	Tons
Neches Butane Products Company, Port Neches	100,000
Sinclair Rubber, Inc., Houston	50,000
Phillips Petroleum Company, Borger	45,000
Humble Oil & Refining Company, Baytown	30,000
Eastern States Petroleum Corp., Houston	12,000
Southport Petroleum Company, Texas City	8,000
Humble Oil & Refining Company, Ingleside	7,700
Taylor Refining Company, Corpus Christi	5,500
Total in Texas	259,000

LOUISIANA

Cities Service Refining Company, Lake Charles	55,000
Standard Oil Company of Louisiana, Baton Rouge	31,500
Total in Louisiana	86,500

ARKANSAS

Lion Oil Refining Company, El Dorado	5,500
Total in Arkansas	5,500
Total in Southwest	351,000

STYRENE MANUFACTURE

Company—	Tons
Dow Chemical Company, Velasco	50,000
Monsanto Chemical Company, Texas City	50,000
Total Styrene	100,000

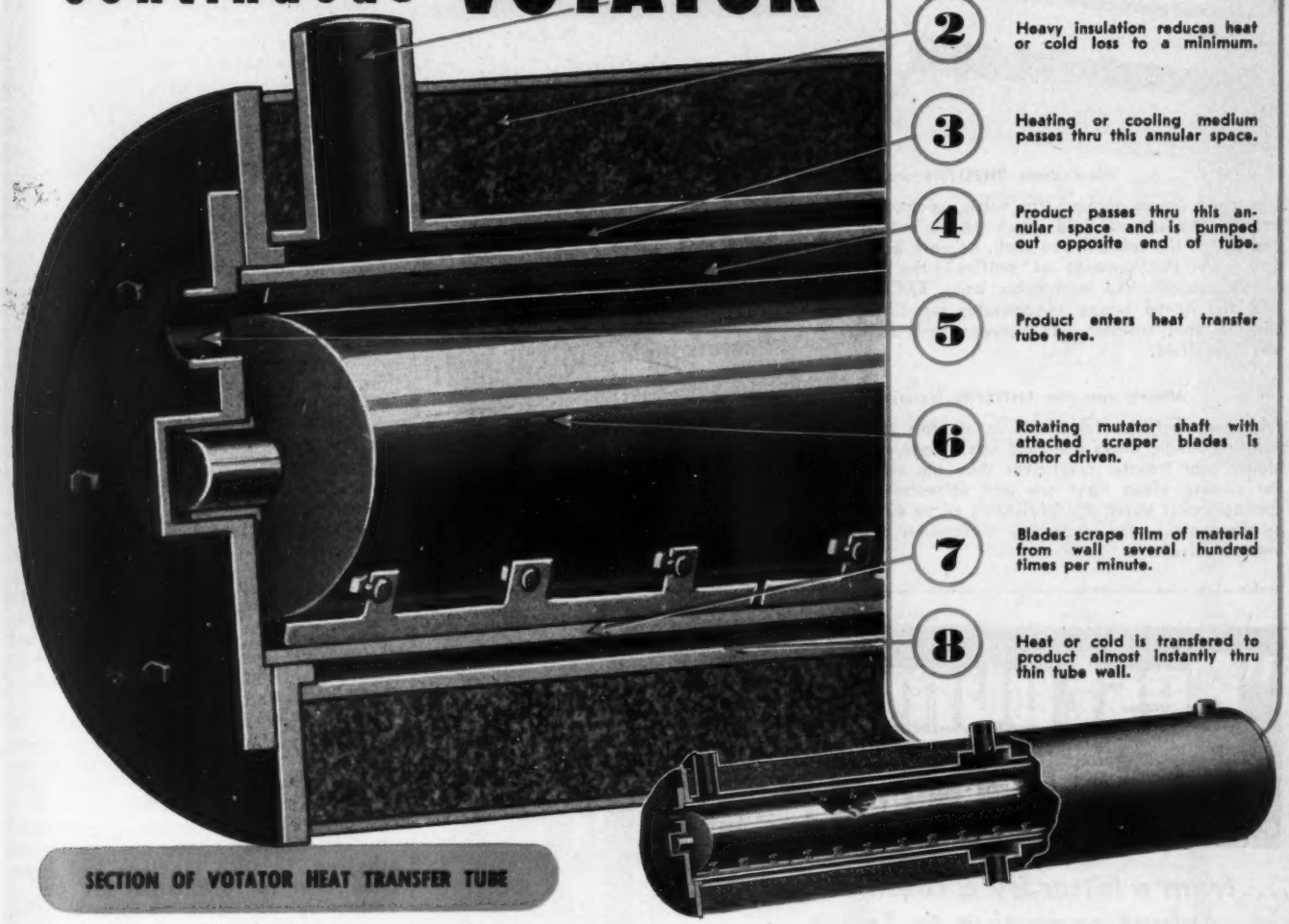
BUNA RUBBER COPOLYMERIZATION

Copolymer Corporation, Baton Rouge	30,000
Firestone Tire and Rubber Company, Lake Charles	60,000
Firestone Tire and Rubber Company, Port Neches	60,000
General Tire & Rubber Company, Baytown	30,000
The B. F. Goodrich Company, Borger	45,000
The B. F. Goodrich Company, Port Neches	60,000
Goodyear Tire & Rubber Company, Houston	60,000
Total Buna Rubber	345,000

BUTYL RUBBER COPOLYMERIZATION

Humble Oil & Refining Company, Baytown	30,000
Standard Oil Company of Louisiana, Baton Rouge	38,000
Total Butyl Rubber	68,000
Total Rubber Manufacture	413,000

Heat or cool refinery products *faster* with continuous VOTATOR


Heart of the VOTATOR is the heat transfer cylinder . . . . . .
1 Heating or cooling medium enters here, is discharged at opposite end of tube.
2 Heavy insulation reduces heat or cold loss to a minimum.
3 Heating or cooling medium passes thru this annular space.
4 Product passes thru this annular space and is pumped out opposite end of tube.
5 Product enters heat transfer tube here.
6 Rotating mutator shaft with attached scraper blades is motor driven.
7 Blades scrape film of material from wall several hundred times per minute.
8 Heat or cold is transfered to product almost instantly thru thin tube wall.

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The above section of a Votator heat transfer cylinder illustrates how heating or cooling can be accomplished in *seconds* and in a continuous manner. The product is pumped in at one end, heated or cooled to a uniform temperature, and discharged at the other end at the temperature desired.

High speed agitation under pressure in the Votator assures thorough mixing simultaneous with heating or cooling. Because the Votator is enclosed, all air and moisture is excluded. However, if desired, any predetermined amount of inert gas may be pumped into the Votator cylinder and incorporated with the product at the time of heat transfer.

A Votator is extremely simple to operate. Adjustments in operating conditions can be made quickly, and results are immediate. Automatic controls and regulators safeguard against carelessness or negligence.

The speed of heat transfer, accurate temperature control, rapid, continuous flow, and the fully enclosed unit are Votator features that result in operating economies not possible with ordinary types of heat exchange equipment. The added advantage of simultaneous mixing or emulsifying also will reduce processing costs and save time.

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the STANDARDIZED shell & finned tube HEAT EXCHANGER

*Pat. Applied for

How does SHELLFIN work?

One fluid passes through the tubes, cooling or heating the second fluid which passes outside and across the tubes in the shell, its path being directed by the "segment cut" baffles in the tube bundle, exactly like most other units, EXCEPT that the finned tubing compensates for difference in heat transfer rate between shell fluid and tube fluid.

Where can the SHELLFIN be used?

Principally between two fluids in medium temperature range, where one fluid has a materially higher heat transfer coefficient than the other. For cooling clean light oils and solvents—for cooling jacket water and lubricating oil on diesel or gas engines—for condensing refrigerants and organic solvents.

What is the SHELLFIN?

It is a *standard design* shell and finned tube heat exchanger conceived and developed by Downingtown engineers to be built on a cost-saving, time-saving production basis. With only minor changes in its construction, such as baffle spacing and length combinations of units, it meets the conditions found in a wide variety of uses for heat exchangers.

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2. Repacking interruptions reduced to a minimum.
3. To compensate for non-lubricating properties of liquid or other chemical solutions pumped, larger bearings are used.
4. Damaging vibration is prevented by larger shaft diameters.

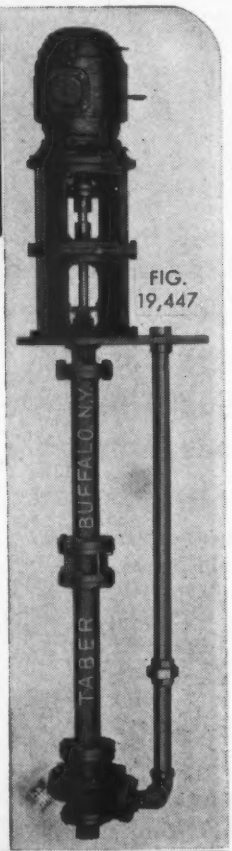

FIG. 19,447

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AD NO. 5414

TABER Pump Co. 277 ELM STREET BUFFALO, N. Y. *Established 1859*

program that grew out of the loss of Singapore in 1941. It has been financed by the federal government and will cost $700,000,000 when complete. Oil companies, rubber companies and chemical companies are operating the plants as lessees.

The part being played by the oil industry represents advancements in refining processes. In large measure this consists of providing butadiene, which is turned over to the rubber industry for combining with styrene and other chemicals to form Buna S rubber.

Butyl rubber is an exception, since it consists of petroleum ingredients only and is made by the petroleum industry.

There are three methods of making butadiene incorporated in this part of the program. Oil can be heated to high temperature, around 1350° F, then suddenly contacted with steam with the result that a portion of the charge becomes butadiene, a gas similar to butane. This process is known as the refinery conversion (quickie) method and will provide less than 50,000 tons of annual capacity.

Another method is to start with butane, one of the more plentiful gases, which can be recovered from crude oil storage, segregated in natural-gasoline manufacture or from cracking still operation in refining. Butane has to be processed twice to make butadiene. The first processing removes two atoms of hydrogen from each molecule and leaves butylene, which is successively processed and two more hydrogen atoms removed to leave butadiene.

The method responsible for the greater part of the butadiene, however, calls for one step of processing. In the new catalytic refining processes operation is so controlled that high yields of butylene result. The butylene is put through one step of hydrogen removal to make butadiene.

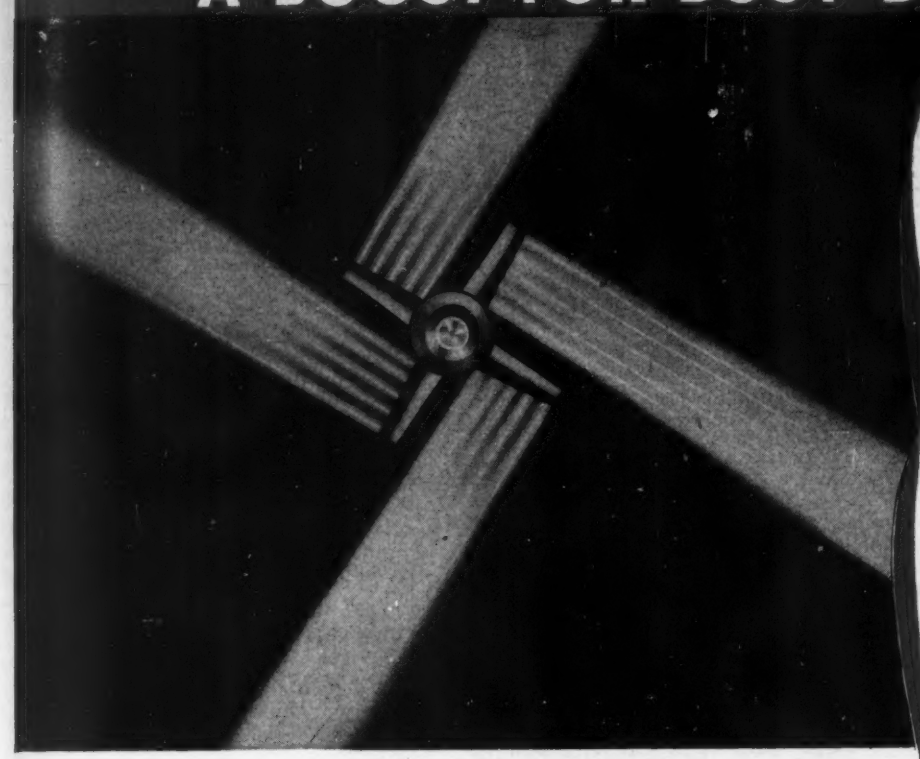
Styrene manufacture in Texas and in California will be through processes developed for petroleum refining and propane, a gas common to natural gasoline processing, will be one part of the raw material. Propane is thermally cracked under conditions that form ethylene. In turn ethylene and benzol from coal tar distillation are put together by alkylation to form ethylbenzene. Finally ethylbenzene is processed by removal of hydrogen atoms to leave styrene.

Butadiene and styrene are the leading ingredients of Buna S rubber. These and other chemicals, brine, sulphuric acid and soap solution are the combination which are mixed with a catalyst to the end that a product similar to natural latex is formed.

The ceremonies in Baytown and Houston had connection with Washington through radio speeches by Jesse H. Jones, Secretary of Commerce; Albert Thomas, Congressman from Houston; R. E. Thomason, Congressman from El Paso. Other speakers included William O'Neil, president of General Tire & Rubber Company; H. Stuart Hotshkiss, president of General Latex & Chemical Company; Harry C. Wiess, president of Humble Oil & Refining Company, and Governor Stevenson of Texas.

The copolymerization plant of 30,000 tons annual capacity will produce latex equal to the output of 100,000 acres of rubber plantation, which would represent an investment of $27,000,000 and

A BOOST FOR BUSY BOILERS...



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With a Coppus-Dennis FANMIX on the job, you get much greater heat release per cubic foot of furnace volume. Gas escaping from radially spaced orifices in the driving arms rotates the fan; causing in-take of air at right angles to the path of the gas.

The energy in gas under pressure is utilized to perform work by mechanically mixing and proportioning the gas with just the proper amount of air, thus eliminating from the furnace the necessity of serving as a mixing chamber as well as combustion space.

Ignition is instantaneous, and combustion is so complete that no flame is visible. A constant temperature exists throughout the furnace — there are no drifting "hot spots". On new equipment, FANMIX saves combustion space, stack height and the cost of forced draft equipment.

Write for free Booklet 410-3 describing other exclusive fuel-saving, equipment-saving advantages of Coppus-Dennis FANMIX Gas Burners — a Coppus "Blue Ribbon" product.

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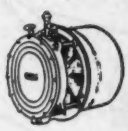
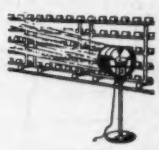


☐ Coppus Type C Turbo Blower. For undergrate draft. Bulletin 145-6.



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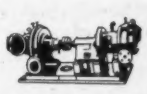

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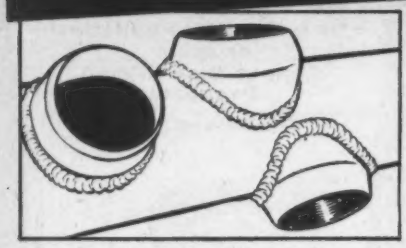
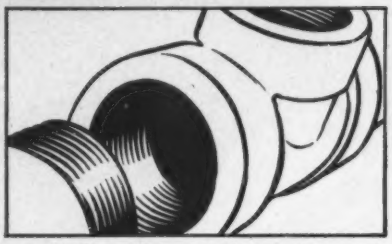
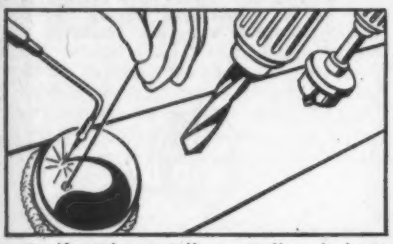
HOW W-T'S* SPEED UP PIPING INSTALLATIONS



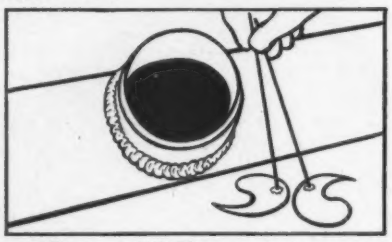
1. Branch pipe outlets can be made with W-T's* anywhere on the main pipe without the use of templets.



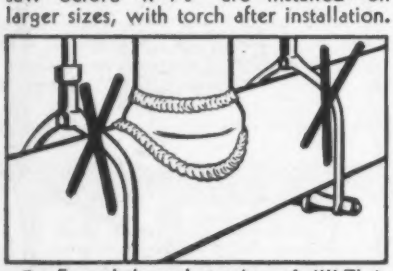
2. W-T's* eliminate all threading and fitting of main pipe in making branch pipe outlets.



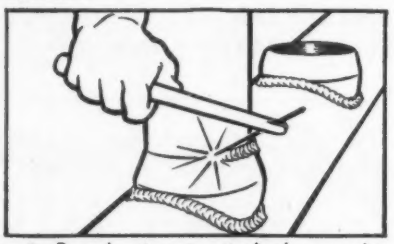
3. If outlet is 2" or smaller, hole is cut in the main pipe with drill or hole-saw before W-T's* are installed—on larger sizes, with torch after installation.



4. The use of W-T's* permits inspection of inside of joint, removal of scale and excess weld metal before branch is attached.



5. Funnel-shaped intake of W-T's* reduces vibrational stress at junction—eliminates need of extra braces and hangers.



6. Branch pipe is attached to outlet of fitting by welding—or, if outlet is threaded by screwing into outlet of fitting. W-T's* provide leakproof junction of full pipe strength.

W-T's* are suitable for all commonly used pressures and temperatures in every type of piping system. They can be installed before or after erection of the main line with ease and economy. Equally well adapted to pre-fabricated or "on-the-job" assemblies. Cost no more—in many cases less than ordinary fittings without their advantages. Stock fittings of drop forged steel, but to meet special conditions can be supplied in Monel, Everdur, Toncan Iron, wrought iron, etc.

Write for Bulletin WT-31 giving complete description of all advantages.

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Beveled outlet of WELDOLETS permits branch pipe to be attached with plain butt weld.

Threaded outlet of THREDOLETS permits branch pipe to be screwed into outlet of fitting.

Outlet of SOCKET-END WELDOLET is bored to accept standard outside pipe diameters. Junction is completed with weld around top of fitting.

All 3 types available for all standard pipe sizes up to 24".

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require at least six years to gain production. The plant can be built for a third of the plantation cost in less than a year. A rubber plantation of 100,000 acres would require 25,000 workers, while the plant will be operated by 350 men.

Build Oklahoma Plant For Aviation Gasoline

Completion of the new refining plant of Associated Refineries, Inc., in Southern Oklahoma will give that state its first refinery built for the production of finished 100-octane gasoline. The venture is being built by a combination of eight refining companies: Bell Oil & Gas Company, Tulsa; Ben Franklin Refining Company, Ardmore; Cosco Oil Company, Davis; La Salle Petroleum Corporation and Panhandle Refining Company, Wichita Falls; Rock Island Refining Company, Duncan, and W. T. Waggoner Estate, Electra, Texas.

Officials of the company are L. B. Simmons, president of Rock Island Refining Company, chairman of the board; M. L. Freese, Bell Oil & Gas Company, president and general manager. Other directors are B. I. Lubell, R. V. Anderson, J. S. Cosden, Jr., L. H. Prichard, R. C. Stanford, P. D. Williams and H. B. Alspaugh.

The eight member companies are making changes in equipment and operations in their plants so as to fill their parts in the contract to contribute certain raw materials to the new plant. Each will continue to operate its own plant.

The combination venture will cost about $10,000,000 and is being financed through Defense Plant Corporation. The catalytic units for the production of aviation gasoline were designed by Universal Oil Products Company and will be operated under license from that company. Construction is being done by Frick-Reid Supply Corporation, Tulsa.

The catalytic-cracking unit is of the fluid-flow type, similar to that recently completed at the Bayway plant of Standard Oil Company of New Jersey. Other catalytic units include hydrogen-fluoride alkylation and an isomerization unit, each licensed by Universal Oil Products Company.

The catalytic units are of latest design, which makes possible the production of aviation gasoline base stock as well as alkylates for blending to desired specifications. Flexibility of operations makes it possible to meet variation in specifications. While the plant is being built especially for production of a war material, it can easily be adapted to peacetime production because of its flexibility.

Raigorodsky Leaves PAW Natural Gasoline Section

Paul M. Raigorodsky resigned July 1 as assistant director of the natural-gas and natural-gasoline section of the Petroleum Administration for War. He will return to private business, being vice president and general manager of Petroleum Engineers, Inc., and Glen Rose Gasoline Company, Tulsa.

Raigorodsky joined the governmental agency in September, 1941, when it was designated Office of Petroleum Coordinator.

Crude Oil Prices and Conservation

JOHN D. GILL*
The Atlantic Refining Company

Before the Quarterly Meeting of Interstate Oil Compact Commission, Pittsburgh, June 26, 1943

MANY countries will be saved from vandalism, and their peoples from terrorism, massacre and enslavement, by the practice of the principles of conservation evolved by the personnel of the oil industry and the oil-regulating bodies of the states which ratified the compact creating your commission.

That eventuality establishes the importance of conservation. Now the practice of conservation is threatened by the federal price-control agency's current policy concerning petroleum prices. To outline the possible serious ultimate consequences of that policy is my present purpose.

I need not take time to tell you how necessary oil is to quick victory over our powerful enemies. It is sufficient to say that we will win the war by our use of unprecedented amounts of oil, vastly exceeding the oil available to the Axis powers. Currently, the American oil industry can produce, conservatively, that is, without waste, approximately 4,600,000 barrels of oil a day. If it were forced to abandon the practice of conservation, as it might have been forced to do if our enemies had been more successful in their attempts to capture the oil resources of other countries, it could produce a substantially greater quantity daily. There would be no question of a shortage of oil with which to bring the war to an early successful termination and with the minimum loss of life and property of the United Nations. We could veritably deluge our enemies with petroleum.

The practice of conservation during most of the last 18 years has led the industry to discover nearly 15 billion barrels of oil in excess of the quantity it has produced. By this means its proven reserves have been increased from 5,300,000,000 barrels at the beginning of 1925 to a little more than 20 billion barrels at the beginning of the present year.

Perhaps it is the existence of this vast productive capacity which has made the Office of Price Administration turn a nearly deaf ear to the industry's petition for a measure of the proved effective means of stimulating the search for additional reserves. That agency exercises vast powers over the production processes of the oil industry through the control of the prices of its raw materials and products. But the very complacency of the agency threatens a breakdown in the practice of the principles of conservation which this commission, its underlying state agencies, and the personnel of the petroleum industry have labored so strenuously to perfect. It is because of the close relation between the practice of conservation principles and the practice of price policies that at this time the members of this commission must of necessity possess a lively interest in the latter policies, as they have heretofore in the former practices.

Were it not for the conservative methods of oil-field development, and of crude-oil withdrawals from reserves, which the commission has so unreservedly sponsored, the oil industry even now might be moving heaven and earth to discover and develop additional oil reserves with which to stave off the enemy. And believe me, if one can judge from the obvious willingness of the Army and Navy to pay productively stimulating prices for the munitions of war which are urgently required, the efforts to find and develop crude-oil reserves would not be restricted by a price policy established to achieve some entirely different and non-productive purpose.

Because of devotion to the anti-inflationary fetish and the complacency to which I have referred, no weighty measures have been adopted for the stimulation of the search for oil, although some exceedingly fantastic suggestions for the subsidization of selected elements of our business have been proposed; and no very effective changes have been made in prices of crude oils, except to a limited extent in the California producing area.

Before proceeding with a discussion of the intimate relation which exists between the prices of petroleum and the conservation of this resource, I should like to offer for your consideration a few figures which establish the validity of the statements already made. At the beginning of the year 1925, according to a generally accepted estimate, the domestic petroleum industry possessed a proven oil reserve of 5,321,427,000 barrels. That reserve was drawn upon freely without regard to the principles of conservation subsequently evolved and promulgated and slowly woven into the practices of the industry. Over the next 18 years, that is, to the first of this year, the industry discovered reserves estimated to yield by conservative methods of production 33,455,778,000 barrels of oil. During this period, the industry produced 18,694,412,000 barrels of oil from the total reserve, by methods each year more and more in accord with the principles of conservation. Consequently, the underground inventory of proven oil increased by 14,761,366,000 barrels. At the beginning of 1943 the reserve contained 20,082,793,000 barrels. Had the industry continued during the 18 years after January 1, 1925 the production practices in vogue at the beginning of the period, and had the demand upon it been as reported, there would have been discovered reserves which in all probability ultimately would have yielded only 20,006,052,000 barrels by those now outmoded production methods. As of the first of this year the proven reserve would have been only about 6,700,000,000 barrels, which is all the reserve necessary for the production of today's supply on a wide-open-flow basis, if each year about as much oil is discovered as is produced. However, the industry and the public would be subjected to all the effects of the vicissitudes of discovery, including violent changes in prices, a characteristic of the industry's affairs over many decades.

Now note please that the difference between the 33 odd billion barrels, which the industry believes it discovered during this period, and the 20 odd billion barrels which it would have reported as discoveries while exerting it-

*E. T. Knight, The Atlantic Refining Company, collaborating on the calculations.

self to supply the 18 odd billion barrels of actual demand, is, to a considerable extent, maybe nearly to the full extent of the 13 odd billion barrel difference, oil that was saved to the country by the practice of the principles of conservation. This vast conservation increment is placed in jeopardy by a price-control policy which ignores the needs of the industry for additions, through price increases, to the revolving fund employed for the whole process of finding oil. Existing reserves are threatened with wasteful depletion as the result of the declining[1] fruitfulness of discovery efforts.

It is conceivable that in the event of an indefinite prolongation of the war, making ever-increasing demands upon the petroleum industry, that withdrawals each year would continue to exceed discoveries; would force the industry to resort to the rapid exhaustion of reserves by practices abhorrent to this commission, bringing about a loss of all, or most, of the 13 billion barrels of reserves which the industry has husbanded through the practice of the principles of conservation. This is a possible price that the public would have to pay for the negation of the Petroleum Administrator's recommendation for a general crude oil price increase of 35 cents per barrel, which is less than 0.85 cents per gallon.

During recent years, indeed continuously to the present time, the production of crude oil has proceeded in an orderly way without the free flowing of wells, or other excessively rapid and wasteful exhaustion of reserves, and, with only minor exceptions, at rates at or below the estimated maximum efficient rates of production. These facts seem to support a view that no one has cause for remonstrance with the price agency's negation of a general crude-oil-price increase on the ground that the negation weakens[2] the practice of conservation. They may satisfy those who pride themselves on being realists, as well as conservationists, with a strong bent to a rigid national price policy, because they are all the facts. But true realists and true conservationists deal not only with the facts of the past and present moment, but also with the probabilities of the future. The probabilities have been forecast by the long-experienced and competent personnel of the crude-oil-price study group of the Cost and Price Adjustment Committee of the Petroleum Industry War Council, and by the crude-oil-production specialists of the Office of the Petroleum Administrator for War. I shall not here go into the details of their reasoning. Their main conclusions may be expressed briefly, as follows:

1. In the near future the demand for petroleum will exceed the currently available maximum efficient supply, necessitating resort to wasteful production;

2. Because of increases in virtually all of the items of cost in the search for and development of reserves, and especially because of the increasing effort required to achieve any given volume of discovery; the capital[3] costs of crude oil properties and the operating costs of producing crude yet to be discovered will be measureably higher than the costs that attach to the reserves heretofore discovered and developed.

But the probabilities cannot be proved. The Office of Price Administration does not consider them inherently factual. Therefore, they are of little concern to that agency. Complacency continues to obsess its mind.

The chief reason for the price-control agency's negation of the industry's claim for an upward adjustment in ceiling prices may grow out of the fact that it is the servant of two masters, and like the servant of the biblical parable, must cleave to one and despise the other. The two masters are respectively: first, the hold-the-line policy of the executive branch of the federal government; and, second, volumes of production necessary to the highest welfare of the nation. Its price policies must serve both masters. The price agency appears to be very much more concerned about the effect of an increase in the price of petroleum upon the hold-the-line policy than upon the industry's ability to satisfy, without waste, all demands upon it, or upon the financial status of producers who are forced now to produce oil for prices which will not yield replacement costs.

The hold-the-line policy, therefore, becomes the primary master and the volume of production to satisfy demand the secondary one. But this is not to say that in its disregard for this secondary master, the agency in charge of price control would openly sponsor, or even indifferently acquiesce to the wasteful production of properties. No doubt that agency would exercise itself to avoid such imputation. But if the committee of the PIWC and the experts of PAW are right in their judgment regarding the imminence of a shortage of supply, an issue may be created which the Office of Price Administration cannot long ignore. Either crude oil must be wastefully produced in order to satisfy total demand, or total demand must be further reduced for the purpose of holding the line. Perhaps it is largely because of a leaning toward the second of these alternatives that the power to ration petroleum products has been invoked. Rationing for cause or by pretext has proceeded to such an extent that the entire demands of our military forces, which have multiplied an unimaginable number of times the peacetime volume, have been and continue to be met, by the deprivation of the civilian population. Indeed the 1943 civilian consumption probably will be 385 million barrels less than it would have been had the war not altered the relatively even tenor of our ways.

If the deprivation of civilians were the only course open for the most vigorous prosecution of the war, there would, of course, be no issue. But the severe restriction of civilian consumption in nearly all parts of the country should be unnecessary; restriction operates to increase the inflationary gap, so abhorrent to the price administration; and in a significant way does violence to the principles of conservation broadly interpreted in terms of the welfare of the people.

When petroleum products are wisely used, many opportunities for a fuller, richer life are provided. I need not attempt to detail the effect of the petroleum-propelled and lubricated automobile upon the development of our American society. It has made possible the better education of our children, especially in rural communities by replacing the one-roomed school by the consolidated school. It has increased the accessibility of natural economic resources of forest and field, mountain and lake; brought a freer social mingling of the people; broken down some barriers between them; and has been the basis for a certain economic progress subtly brought about by the intensification of competition as buyers have been enabled to compare values offered by merchants in different parts of large towns and of merchants in one town with those of another.

Now it well might be that the impacts of the war, which brought about a reduction in the usually employed oil transportation facilities available to the Eastern section of the United States; and the loss, for the time being, of our accustomed source of rubber, might have forced a rigorous restriction in the use of gasoline in that area. But the loss of transportation had little, and the loss of our rubber supply had nothing directly to do with the restrictions in the consumption of that fraction of crude petroleum which ordinarily is employed for the heating of homes and

[1] See Report "On the Study of the Crude Oil Price Structure to Determine Those Factors Which can be Expected to Stimulate and Increase the Rate of Discovery of New Reserves of Crude Oil" by the Committee on Cost and Price Adjustment to the Petroleum Industry War Council, February 3, 1943; See E. De Golyer, before the Annual Meeting, A. I. M. M. E., February 18, 1943.

[2] It appears highly significant that the Petroleum Administrator for War has certified for June, 1943, generally lower production rates to the Eastern and Midwest producing states because of the declining productive capacities of the fields in those areas.

[3] The outlook is for replacement costs upwards of one-third higher than the capital costs of existing productive facilities. (Author)

other peopled buildings. For the year, 1943, the normal expected demand for oils for this purpose totals 238 million barrels. But it appears now that the supply will be more than 69 million barrels, or 29 per cent short of the requirements. This is a serious curtailment which reduces the conveniences and comforts of living and jeopardizes the health of those persons whose homes and places of occupation are heated by petroleum.

From even this brief statement it must be clear that just as "price" is intimately related to the conservation of petroleum, so it is related to conservation in the broad sense of the term[4].

Price Determines Effort

Price determines the character and extent of use and of the competition of other commodities. It also determines the amount of effort which may be expended in the search for reserves, for production therefrom, for transportation and refining. Price always has been the factor which equated supply and demand. In peacetime, price has been a variable moving to any level necessary to perform its equalizing function. But at present the cart and horse are reversed. Price is no longer the free-moving variable to equate supply and demand, but is a constant to restrict the supply to a preconcieved total of demand. This is a condition unfortunate for civilians hungry for petroleum products, but it is the case.

If federal control of prices were concerned only with the maximum wartime production of goods in order of their essentiality, there is no doubt that in the light of diminishing discoveries of new reserves for any given volume of exploratory effort, and in further view of the imminence of a shortage of supply, the price-control agency would long ago have accorded a general increase in the prices of crude petroleums and their products.

Other Elements

But it is conceded that from the viewpoint of the hold-the-linists, the problem of the prices of crude petroleum should not be considered apart from its relations to the price problems of other elements of the economy. The impact of changes in one set of commodity prices upon the costs of many other commodities, and hence upon many other prices, is too well understood to need restating here. However, when the control of the prices of a natural resource like petroleum and its derived products is part of a general price-freezing policy, production is stifled as emphasis is placed more and more upon the main objective, price immobility. When an increase in any price is refused because

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of an assumed or possible effect on other prices in a system which brooks no change in average price, we have, to say the least, an impasse. We experience a diminution in economic welfare.

Moreover, there is a source of cost increases in the case of petroleum which is not related to changes in the unit prices of goods and services entering into its discovery and production. I refer, of course, again to that increment of cost arising out of the increasing difficulty of finding oil. This is a condition peculiar to petroleum. It should be recognized by the price-control authorities and due allowance made for it. Relatively moderate changes in prices, possible now to effect a gradual extension of productive capacity, would avoid violent changes in prices necessitated by shortages developed otherwise in the future. Violent price changes have always been accompanied by inefficiency and waste.

Our industry has learned to live under controls on its oil-production processes. Indeed many of the present oil-field controls have been initiated by the industry; all of them have been implemented by regulations promulgated by appropriate bodies of the compact member-states. But these controls have in the main been either of a police-power nature or designed to deal solely with technical aspects of oil production in order that perfection might be approached in the practice of the principles of conservation. Economic control, to the extent that it has been exercised, has been incidental. The over-all result has been relative freedom from violent changes in the factors of price, supply and demand, except as these have been affected by external forces. But now we are faced with federal economic controls of factors which are not readily susceptible to expression in formulas by technical experts—factors which logically change with the interplay of competitive forces.

Profound, perplexing questions are following in the wake of our current experiences. Many of them will go unanswered in the event of an early termination of the war and a prompt return to a wholesome degree of economic freedom. But there are other questions which must be answered soon if the prospect is for an indefinite prolongation of the war. Some of them center around the character of the existing price control: How long will crude prices be kept at their 1937 price level while the average of all commodity prices is now 20.5 per cent above the 1937 level? How much oil can we afford to waste or what further restriction of civilian consumption impose in order to avoid raising petroleum products prices by about 7 percent?

Pennsylvania Grade Association Warned of Pending Oil Shortage

Agreeing that a price raise of from 75 cents to $1.00 per barrel is necessary to speed up and increase oil recovery, officials of the Pennsylvania Grade Crude Oil Association meeting in Pennsylvania, June 25, urged such a price increase immediately.

"OPA is creating an oil bottleneck that threatens the entire war effort," charged Representative Leon H. Gavin, Oil City, Pennsylvania, as he spoke to the group. "It is a critical situation," he declared, "and it will be a terrible catastrophe if within a few months from now, by reason of the short-sighted policy of OPA, we find ourselves without sufficient oil to fully man the machines of war."

Assistant Deputy Petroleum Administrator Robert E. Allen also warned of an oil shortage. He stated that the United States faces a permanent dearth of petroleum unless exploratory work is increased. "The industry must find new fields, drill new wells and finance new operations. To accomplish this, an adequate price must be established as a national structure."

The oil industry, like all others, is most responsive to the profit motive, Colonel E. O. Thompson, chairman of the Texas Railroad Commission, asserted before the meeting. "Subsidies will not get the oil," he said. "From my experience I would say they will drill for the subsidy and not for the oil." Discovery of a major field every week is necessary to meet the present demand for oil and its products, and to maintain proper reserves, Colonel Thompson declared.

Other speakers were Governor Andrew F. Schoeppel, of Kansas; Rudolph R Cubicciotti of L. Sonneborn Sons, New York; Samuel F. Pratt, general secretary of the association; and Fayette B. Dow, vice president and general counsel.

New officers chosen for the coming year were: D. T. Andrus, Bradford, president; Arthur T. Simmons, Bradford, first vice president; D. T. Ring, Columbus, Ohio, second vice president; Samuel Messer, Oil City, treasurer, and Walter R. Reitz, Oil City, assistant treasurer.

Chemical Society to Meet in Pittsburgh

The 1943 fall meeting of the American Chemical Society will be held in Pittsburgh, September 5 through 10. This meeting is being dedicated to the war effort. Its scientific sessions will be pointed toward the Axis. There will be no plant and field trips and no organized entertainment.

Sessions of the Division of Petroleum Chemistry likely will be held September 9 and 10 and these programs will be general in nature.

J. C. Warner of the department of chemistry, Carnegie Institute of Technology, is general chairman of the local committees.

Because of the housing situation and the nature of the meeting, an effort is being made to restrict attendance to those primarily interested in the sessions. Along this line the announcement read:

"Pittsburgh is not seeking a record attendance. Rather the section desires to make certain that the limited facilities available are used to best advantage. Therefore, it is the society's unpleasant task to request wives and families to forego this meeting in order that available transportation and housing be used to accommodate all chemists and chemical engineers who should attend."

Edgar H. Fallin Joins Pennsylvania Association

Edgar H. Fallin, Audubon, New Jersey, has been appointed Pacific Coast representative of the Pennsylvania Grade Crude Oil Association. He will have headquarters in Los Angeles, where he succeeded Thomas McAuliffe, who resigned in April.

Before undertaking his new duties he studied at association headquarters in Oil City and at the laboratory of The Pennsylvania State College. He left for his Pacific Coast duties after attending the meeting of the association in Pittsburgh, June 25.

Carbon Black Sales and Output Down in 1942

Both production and sales of carbon blacks were lower in 1942 than in 1941 according to the compilation on this product as prepared for the Mineral Industry Survey of the United States Bureau of Mines. Production was only 3 percent below the record year, 1941, sales, however, were down 30 percent, a condition brought about when consumers bought heavily in 1941 in anticipation of a price increase.

A resume of the status of carbon black as prepared by H. Backus under the supervision of G. R. Hopkins, Petroleum Economics Division, follows:

"Stocks held by producers at the end of 1942 were 242,755,000 pounds, the highest level since 1932, when 257,998,000 pounds were reported, and more than double the 118,847,000 pounds in stock at the end of 1941.

"Natural gas burned in the manufacture of the 574,006,000 pounds of carbon black produced in 1942 amounted to 335,533,000,000 cubic feet, 8 percent less than was used in 1941. Carbon-black producers paid an average of 1.29 cents a thousand cubic feet of gas in 1942 compared with 1.13 in 1941.

"An increase in the manufacture of furnace blacks, which have a relatively high yield, caused a further gain in the total yield from 1.54 pounds per thousand cubic feet of gas in 1940 and 1.63 pounds in 1941 to 1.71 pounds in 1942. Furnace blacks comprised 24 percent of the total production of carbon black in 1942, 17 in 1941, 13 in 1940, and 11 in 1939.

"Publication of export figures has been suspended. Total sales in 1942, including exports, were 449,931,000

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FOAM-REDUCER. Centrifuge rotors normally remove entrained air (and impurities) from liquids. But air is then remixed with the liquid as it discharges from the usual rotor. The ingenious liquid take-off shown below removes the purified liquid from the rotor almost foam free. Successfully used to centrifuge apple juice, floor wax, chemicals, etc.

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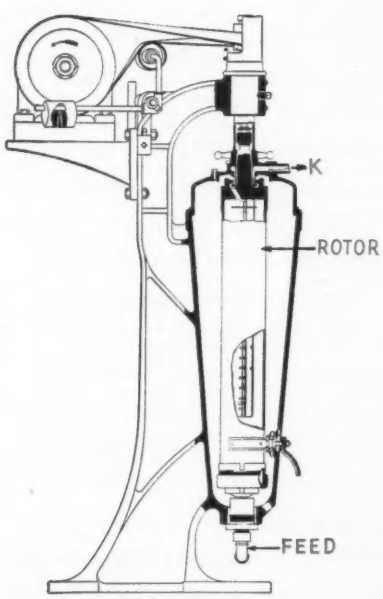

FIGURE 1

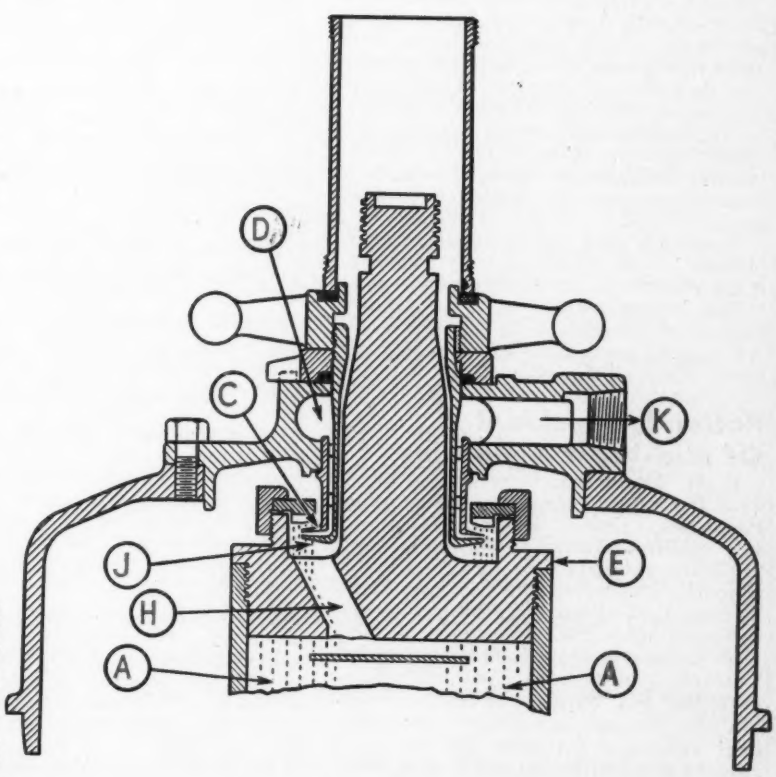

FIGURE 2

Fig. 1 is the complete centrifuge. Fig. 2 shows the head E of the rotor. The liquid A flows continuously into the bottom of the rotor, then out through the top passages H. At J the liquid is revolving rapidly and is, therefore, under a centrifugally generated pressure head. Upon entering the stationary annular take-off C, the liquid will no longer revolve, thus converting kinetic energy to static pressure. The pressure from J thus will force it into D and out K *under pressure* and *without access to air.*

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pounds compared with 644,744,000 pounds in 1941 and 529,774,000 pounds in 1940. In spite of the slump in rubber manufacture, about 89 percent of domestic sales in 1942 went to the rubber trade. Toward the end of the year the demands from the synthetic-rubber industry were taking up some of the slack. Deliveries to ink companies gained slightly from the standpoint of percent of total sales at the expense of sales to paint companies.

"The average value at the plants of carbon black in 1942 was 3.41 cents a pound compared with 3.26 cents in 1941. This is the highest average since 1937 when the same rate was recorded.

"California and New Mexico were added to the list of producing states during the year."

Army Needs More Than Million Barrels Daily

An Army need for 1,000,000 barrels of oil daily during the remainder of this year, not including aviation gasoline or lubricating oil, and a higher demand in 1944 was disclosed to the last meeting of PIWC by Lieutenant General Brehon Somervell, chief of the Army Service Forces.

Those figures and other information given consideration in the Army supply bill for the approaching fiscal year, it is understood, were one of the reasons for the decision of Senator Thomas of Oklahoma, chairman of the subcommittee in charge of the measure, to call industry representatives to testify regarding the possibility of filling the military requirements on the basis of present price ceilings.

Somervell told the council that 50 percent of all Army overseas tonnage is oil.

The requirements of the military forces are determined by an Army and Navy joint petroleum board which reports direct to the joint chiefs of staffs.

Potter Is President Of Mid-West Refineries

E. W. Potter has been elected president and general manager of Mid-West Refineries, Grand Rapids, Michigan. His promotion from executive vice president followed the death of B. J. Skinner, founder of the company, who died in April. Potter has been with the company since 1940. Previously he was with Universal Oil Products Company, Chicago, and Cosden Petroleum Corporation, Big Spring, Texas.

V. M. Skinner was elected vice president and sales manager. He has been associated with the company since 1934.

Sohio Plant Wins Ohio Safety Award

The No. 1 refinery of Standard Oil Company of Ohio has won permanent possession of the award of the Ohio Safety Commission within the refining industry of the state because of its record over the past years. The award went to the plant for having no lost time accidents for the highest total of man hours during six consecutive months. By winning three times the plaque came into permanent possession of the personnel of the plant.

The plaque was given to C. H. Metz, Jr., plant superintendent, by Frank Klett of the Ohio Safety Commission.

Company Organized to Promote Sound Financing Mexican Enterprise

Organization by leading Mexican and United States financiers and industrialists of Financiera Tecnica de Mexico, S. A. to promote sound financing of Mexican enterprise and to furnish technical and managerial services in the organization and operation of Mexican business has been completed. The company has been formed under a concession granted under the General Law of Banking Institutions and Auxiliary Organizations of Mexico, and has established offices at Venustiano Carranza 53, Despacho 11, Mexico, D. F.

Financiera Tecnica de Mexico, S. A., is interested in assisting the direction along sound lines of Mexico's industrial development which has been greatly stimulated under the conditions of prosperity created by the war. Its facilities and experience will be available both for the expansion of existing businesses and for the establishment of new enterprises for which the need exists in Mexico today, or which will contribute to building a position for that country in the organization of post-war world trade commensurate with Mexico's natural resources.

While the concession under which the company will operate authorizes a role in finance comparable to that played by private bankers in the development of business in this country, chief emphasis, as contemplated by present plans, will be on providing technical and managerial counsel and services, with the financing function incidental to and integrated with these services.

Those interested in this new enterprise and serving as directors include Julio Lacaud and Carlos Trouyet, partners of J. Lacaud y Cia., investment bankers of Mexico City; Antonio Espinosa de los Monteros, director general of Nacional Financiera, S. A., Mexico City; and George H. Houston and Hendrik R. Jolles, partners of the firm of Houston & Jolles, consultants in the financing and management of industry, New York. Jolles is managing director of the company.

Lacaud has long been prominently identified with Mexican industry and banking, being a member of the board of directors of many leading companies. Trouyet is president of the Mexico City Stock Exchange and is active in Mexican enterprise.

Espinosa de los Monteros in his capacity as director general of Nacional Financiera, S. A., has had much to do with the vitalization of Mexican finance and industry. He is a director of other important industrial and financial companies.

Houston, prior to the formation of Houston & Jolles, has been actively identified with industrial management for many years, having served from 1929 to 1938 as president of The Baldwin Locomotive Works. Previously he reorganized and managed a large group of sugar properties in the West Indies and during the first World War, as a partner in the engineering firm of George W. Goethals & Company, was president of Wright Martin Aircraft Company and its successor, Wright Aeronautical Corporation.

Jolles has devoted much of his career to investment banking, most of his experience having been in the international field. He retired as vice president and director of Harriman Ripley & Company to establish his present association with Houston in 1940.

H. L. Farrar Elected Trustee of Gas Institute

H. L. Farrar, president of Coast Counties Gas and Electric Company, San Francisco, was elected to the board of trustees of the Instiute of Gas Technology at the June meeting. He is the only new member of the board and took the place left vacant by A. R. Bailey, of the same company, who is now in the armed forces.

Trustees, whose terms expire in 1943, were up for reelection at the annual meeting and the following were returned to the board for three-year terms: W. Alton Jones, president of Cities Service Company; Alfred O. Kauffman, retired president of Link Belt Company; Frank H. Lerch, Jr., president of Gas Companies, Inc.; Clifford E. Paige, president of Brooklyn Union Gas Company; Louis Ruthenberg, president of Servel, Inc., and Wilfred Sykes, president of Inland Steel Company.

All officials of the institute were reelected: Frank C. Smith, president of Houston Natural Gas Corporation, chairman; Henry T. Heald, president of Illinois Institute of Technology, president; Harold Vagtborg, director; Robert B. Harper, vice president of Peoples Gas Light and Coke Company, secretary; Raymond J. Spaeth, treasurer of Illinois Institute of Technology, treasurer.

West Coast Styrene Unit Goes Into Production

The first unit of the styrene plant of Dow Chemical Company in the Los Angeles area has been put into production six weeks ahead of schedule. Its output will form a part of the synthetic-rubber production of the area. Adjacent to the Dow plant is the butadinene plant of Shell Oil Company and rubber polymerization plant of Goodyear Tire and Rubber Company.

The plant and the process were described as follows in information released by Dow Chemical Company:

"Dow's experience in the field of styrene dates back to 1936 when this chemical product was produced on a commercial scale at Dow's main plant at Midland, Michigan. Incidentally, this new Los Angeles unit is the fourth plant, of this type, built by Dow.

"In terms of easing our critical rubber requirements, this new Los Angeles unit is producing sufficient styrene each day to permit the manufacture of more than 14,000 passenger car tires. When the second unit is brought into production, which is scheduled for August, the total equivalent will be almost 30,000

Wilson Trigger-Power Cleaner with Wilson Vibromatic Attachment

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For cleaning tubes which are partially or totally plugged with especially hard deposits such as "petro-coke", hard silica scale, etc., the use of the Wilson Vibromatic Attachment in conjunction with the Wilson Trigger-Power Cleaner makes the operation remarkably easy and rapid. The Attachment gives the special Wilson "Cutter-Bit" the combined movement of a rotary tube cleaner and a percussion hammer. It adds a series of rapid blows to the rotation of the "cutter-bit" and at the same time enables it to obtain a good "bite" on the deposit. This dual-action of the "cutter-bit" quickly breaks up and removes the hardest and heaviest deposits. The Wilson Vibromatic Attachment is operated by the air or steam used as scavenging agent for cleaning the tube of debris, and its use in no way reduces the power of the Trigger-Power Cleaner's motor.

Send for Bulletin No. 63 which fully describes this remarkable tube cleaner.

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passenger car tires per day or almost 11 million per year.

"An important point about this new plant is the utilization of a large number of regulating instruments that enable the plant to operate almost automatically and also maintain extremely close control on the quality of the finished product. Many of these instruments are of special types designed by Dow instrument engineers in cooperation with well-known precision instrument manufacturers.

"With the completion of this plant, together with Dow's other producing facilities, this company has taken a leading role in the American production of styrene so essential to our synthetic rubber program.

Second HF Alkylation Plant in Operation

Second hydrofluoric acid alkylation plant of Phillips Petroleum Company has been put in operation as part of the 100-octane gasoline program of the company. The company now has nine refining units supplying finished aviation gasoline ingredients for its completion.

Information from the company on the latest unit is as follows:

"This new plant uses the recently developed HF alkylation process and is the second plant to be completed that uses this improved process. The first HF alkylation plant was also built by Phillips Petroleum Company and was put into operation last year. The fact that the alkylate produced in these two plants will make several times as much 100-octane aviation gasoline as was being used by the United States Air Forces immediately before World War II indicates the expansion that has been accomplished in the production of aviation gasoline. Many other companies are constructing HF alkylation plants and will soon complete them, but the Phillips research department discovered the basic principle of the reaction involved, Phillips research chemists developed this better process, Phillips engineers designed the plant to use it, and this close association has enabled Phillips to finish their two plants in record time."

LPG Section Formed As Part of PAW

A liquefied petroleum gas section within the division of natural gas and natural gasoline has been formed under the Petroleum Administration for War. The formation was in effect a transfer of personnel headed by Paul K. Thompson from the War Production Board, where the distribution and handling problems of liquefied petroleum gases came under direction of the plumbing and heating division.

The section continues the functions for which it was responsible in WPB, principally the administration of limitation order L-86 which regulates the installation of liquefied petroleum gas equipment.

Liquefied petroleum gases affected by the L-86 order are butane, propane and mixtures of these two hydrocarbons.

Laboratory to Study Butane Conversion

A study directed toward finding a process whereby butane can be converted directly to butadiene will be the first duty of a staff of technologists, who will work in a new laboratory of the Bartlesville Experiment Station of the United States Bureau of Mines. Dr. Hugh M. Huffman, recently on the staff of the California Institute of Technology, has been selected to direct this research.

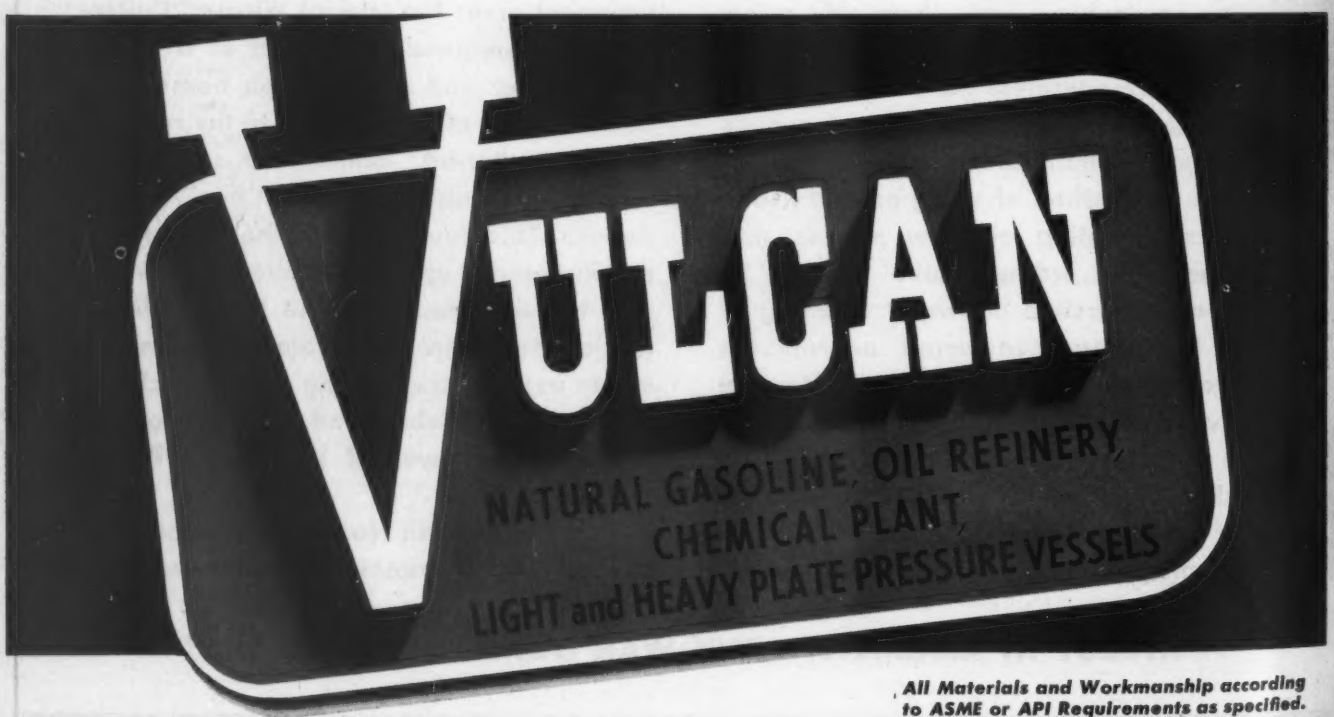
Processes now available involve converting butane to butylene and then to butadiene, two steps of dehydrogenation.

The general purpose of the laboratory will be the determination of the thermodynamic properties of hydrocarbons and their derivatives.

Dr. Hoffman is an outstanding authority on physical chemistry. He was educated at Stanford University, where he earned his Ph.D. in 1928. He was a research associate of the American Petroleum Institute at Stanford from 1927 to 1931, when he went to California Institute of Technology as assistant professor of biochemistry.

Refining Committee of PIWC Is Increased

The standing committee on refining of the Petroleum Industry War Council was one of those to get additional members as a result of action taken at the meeting June 2. Enlargement of five of the functional standing committees was approved in order to amplify com-



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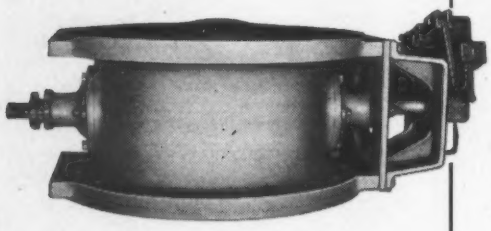

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mittee activities and to afford broader degree of representation.

Those added to the committee on refining of which R. H. Colley, The Atlantic Refining Company, Philadelphia, is chairman, are: Harry A. Logan, United Refining Company, Warren, Pennsylvania; C. L. Henderson, Vickers Petroleum Company, Wichita; F. E. Holsten, vice president of Chalmette Refining Company, New Orleans, and C. A. Johnson, Socal Oil & Refining Company, Los Angeles.

E. O. Bennett Petroleum Consultant

E. O. Bennett, former chief petroleum engineer for Continental Oil Company, has opened an office as petroleum consultant at 324 Mellie Esperson Building, Houston. His resignation was announced June 15.

He had been with Continental Oil Company since 1926, having served as chief engineer, assistant manager of production and chief petroleum engineer, and has devoted much of his time to field operations along the Gulf Coast. He is recognized as an authority on oil production methods, particularly in pressure-maintenance operations in high-pressure fields, and has been granted a number of patents for pipe-line, drilling and production equipment. Active in the industry's association activities, he has contributed extensively to the literature. For his contributions to the natural-gasoline industry he was given the Hanlon Award in 1942 for distinguished service to that branch of the industry, and more recently was awarded the degree of doctor of engineering by Texas A. & M. College, "in recognition of his outstanding contribution to engineering science."

Source Information On Synthetic Rubbers

United States Bureau of Mines has compiled a reference publication listing the various types of synthetic rubber, the manufacturers, materials required and methods of manufacture. It is "Synthetic Rubber," Information Circular No. 7242, available through United States Bureau of Mines, Department of the Interior, Washington, D. C.

The circular was written by W. C. Holliman, assistant research chemist at the petroleum experiment station at Bartlesville. It is prefaced by a description of the principal raw materials used in synthetic-rubber synthesis, butadiene, styrene, acrylonitrile, chloroprene, isoprene, dimethlbutadiene, idobutylene, alkali polysulfides, organic dihalides and vinyl chlorides.

No Price Limitations On Catalyst Materials

Catalysts sold for use in the manufacture of aviation gasoline were removed from price control June 11 by OPA in line with its policy of exempting aviation gasoline and synthetic rubber, as well as a number of commodities used in their manufacture, from price restrictions.

It was explained that this policy was based on a realization that production cost experience of the industry has been too recent and, because of vast experimentation, factors are too varying to be sufficiently indicative for price-control studies.

PAW Not Favored as Rationing Agency

Prospects for transfer of control of oil rationing from OPA to PAW dimmed last month, when President Roosevelt made known his unalterable opposition to dismemberment of the price agency, proposed in Congressional pleas for a food "czar" with over-all control.

The President's firm stand was voiced almost on the heels of another reportedly stormy session of WPB at which Ickes renewed his demand for control of oil against the vigorous opposition of other members of the board.

Ickes reportedly pulled no punches in saying what he thought of rationing and price control as now practiced by OPA, elaborating upon criticisms he had made earlier before members of Congress inquiring into the Eastern gasoline situation.

Mr. Roosevelt, although he devoted himself to a discussion of the question as it related to the food problem, made it clear that he has no intention of splitting up OPA and criticised loose thinking which led to the idea that a "czar" was the answer for every ill.

He agreed that there have been delays in the handling of many matters as a result of divisions in authority, but said the new OWN was prepared to coordinate the work of the sepaarte agencies and eliminate delays and asked that Director Byrnes be given a chance to apply the rule of judgment instead of what he called the rule of happy thought.

Light Oils Handbook

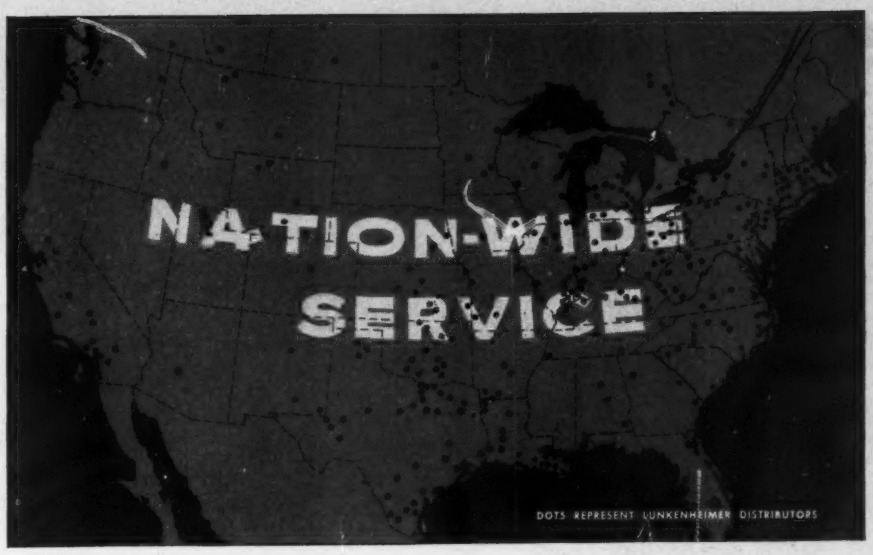
This new publication, "Gas Chemists' Book of Standards for Light Oils and Light Oil Products," represents an effort to complete a work because of its pressing need in the war effort. It is the expansion of one section of the revision into a complete volume. It was prepared by V. J. Altieri, Eastern Gas & Fuel Associates, Everett, Massachusetts. The complete revision of the Gas Chemists' Handbook of the American Gas Association, is under the direction of E. L. Sweeney, Boston Consolidated Gas Company.

To members of American Gas Association the volume sells for $3.50, to non-members, the price is $5, from American Gas Association, 420 Lexington Avenue, New York. Scope and purpose of the revision has been explained in the foreword as follows:

"Today there is a demand for enormous quantities of benzene, toluene, xylenes, solvent naphthas and other light oil products. Whether these materials are used for munitions, aviation motor-fuel, plastics, synthetic rubber, intermediates or other products the question of quality is of great importance . . . "

From the preface:

"The purpose of this book, therefore, has been to explain simply and accurately the details of current specifications, definitions, tests and facilities already established in matters relating to light oil and light oil products. The objective has been to furnish information that will help speed up production, avoid unnecessary changes in equipment, reduce non-essential demand for strategic or critical materials, facilitate the formulation of new standards and thus aid the war effort."



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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Thermodynamic Properties of Propane, W. V. STEARNS AND E. J. GEORGE, *Ind. & Eng. Chem.* **35** (1943) pp. 602-7.

The use of propane as a refrigerant has increased greatly within the last few years, and thermodynamic data for this refrigerant have not been compiled for the whole region normally employed in regrigeration. The authors' paper represents a close correlation of the published experimental data of a number of investigators on certain phases of the thermodynamic properties of propane. A detailed table showing the temperature data for saturated propane from —80° F. to 200° F. is included. The properties covered are temperature, pressure, volume of liquid and vapor, density of liquid and vapor, heat content of liquid and vapor, latent heat, and entropy of liquid and vapor. A second table presents properties of superheated propane vapors from —70° F. to 200° F. and at several pressures from 15 inches of mercury to 300 pounds absolute. Charts are presented showing absolute enthalpy for propane and the entropy temperature chart for propane.

Some Physical Properties of Butadiene and Styrene, L. A. WOOD AND C. F. HIGGINS, *India Rubber World* **107** (1943) pp. 475-6.

Data for 1,3-butadiene and styrene are given for boiling point, freezing point, density of vapor, density of liquid from —20 to 60° C. for butadiene and 0° to 145° C. for styrene, the thermal expansion of liquid for butadiene from —20° to 60° C., rate of change of density of styrene from 0° to 145°, vapor pressure of butadiene from —80° to 40° C. and of styrene from —8° C. to 145° C., rate of change of boiling point with pressure, heat of vaporization at normal boiling point, heat of fusion, heat of formation of vapor of butadiene at 25° C., heat of combustion of vapor of butadiene at 25° C. at 1 atmosphere of pressure, specific heat at 25°, refractive indices, rate of change of refractive index with temperature from 17° C. to 26° C., limits of flame propagation in mixtures of the substances with air, and surface tension of styrene at 19° C. A bibliography of references is included from which the data were derived. However, some of the data included are hitherto unpublished.

The Thermodynamics and Molecular Structure of Benzene and Its Methyl Derivatives, K. S. PITZER AND D. W. SCOTT, *Jour. Am. Chem. Soc.* **65** (1943) pp. 803-29.

The heat capacity of solid liquid and gas in appropriate ranges from 15 to 470° K., the heats of fusion and vaporization, the melting points and vapor pressures, the entropies of liquid and gas, the free energy function $H°O—F°T/T$, the heat content, and the heat capacity over the range 298-1500° K. were measured or calculated for the substances: benzene, toluene, o-, m- and p-xylene. The freezing point diagram for the ternary system o-, m- and p-xylene was calculated and certain points experimentally verified. The direct isomerization reaction of the xylenes, catalyzed by aluminum bromide and hydrogen bromide, led to a direct measure of the equilibrium composition. Using the same catalyst, the equilibrium constant for the reaction 2 toluene = benzene + xylene at equilibrium was found to be between 0-15 and 0-22 at 323° K. From these data the various thermodynamic constants for the isomerization and for the toluene, benzene, xylene reactions were calculated. The melting point, heats of fusion, heats of vaporization, vapor pressure, entropy, entropy of the gas for ortho, meta, and paraxylene are given. Various thermodynamic functions were calculated for mesitylene from molecular structure data, the entropy of the gas at 298° K. being 92.34 calories per degree. The entropies of pseudocumene (1,2,4-trimethylbenzene) and durene (1,2,4,5-tetramethylbenzene) were estimated to be 94.2 and 98.5 Calories per degree, respectively, in the gaseous state at 298° K. By consideration of the lines appearing in the infra-red and Raman spectra of liquid benzene in violation of the simple selection rules, it was possible to complete the assignment of fundamental vibration frequencies. Although a few values are not certain, all are reasonable from the point of view of the force constants of the benzene molecule. The spectra of the simpler deuterated benzenes were also considered. The fundamental vibration frequencies were selected for toluene, the three xylenes, and mesitylene using Raman and infrared spectra from the literature. Attention is called to the striking behavior of the 1000 cm.-1 line in benzene derivatives which are substituted in only 1,3,5-positions. Corresponding effects are observed where the trigonal positions are all similarly substituted. It is suggested that the Raman spectra might be used to determine the position of substituents in favorable cases. Using these frequencies the vibrational entropy and heat capacity contributions can be calculated and the corresponding quantities for internal rotation of the methyl groups obtained. The results indicate relatively free rotation of methyl groups in toluene, m- and p-xylene, but only about a 2000 calorie potential barrier for o-xylene. These results are shown to be reasonable in terms of steric effects. The xylene equilibrium data show the meta compound to have lowest energy and suggest that meta orientation of identical or similar groups may be generally the most stable.

The Pressure - Volume - Temperature Relations of 2,2,4-Trimethylpentane, W. A. FELSING AND G. M. WATSON, *Jour. Am. Chem. Soc.* **65** (1943) pp. 780-1.

This is a continuation of the work in the chemical laboratory of the University of Texas on the physical properties of pure hydrocarbons. The compressibility of pure liquid isooctane, 2,2,4-trimethylpentane, has been determined at 25° intervals from 100° to 250° at pressures ranging from the vapor pressures to 300 amospheres. The compressibility was determined at one temperature, 275° C., above the critical point. Compressibility measurements were made by means of a dead-weight piston gage and accessories that have been described elsewhere. The data are presented in tabular and graphical form, the specific volume being related to the pressure at different temperatures.

Composition of Vapors from Boiling Binary Solutions, D. F. OTHMER, *Ind. & Eng. Chem.* **35** (1943) pp. 614-20.

The composition of vapors resulting from boiling solutions of binary liquids or, as usually expressed, vapor-liquid equilibrium data, can be readily and

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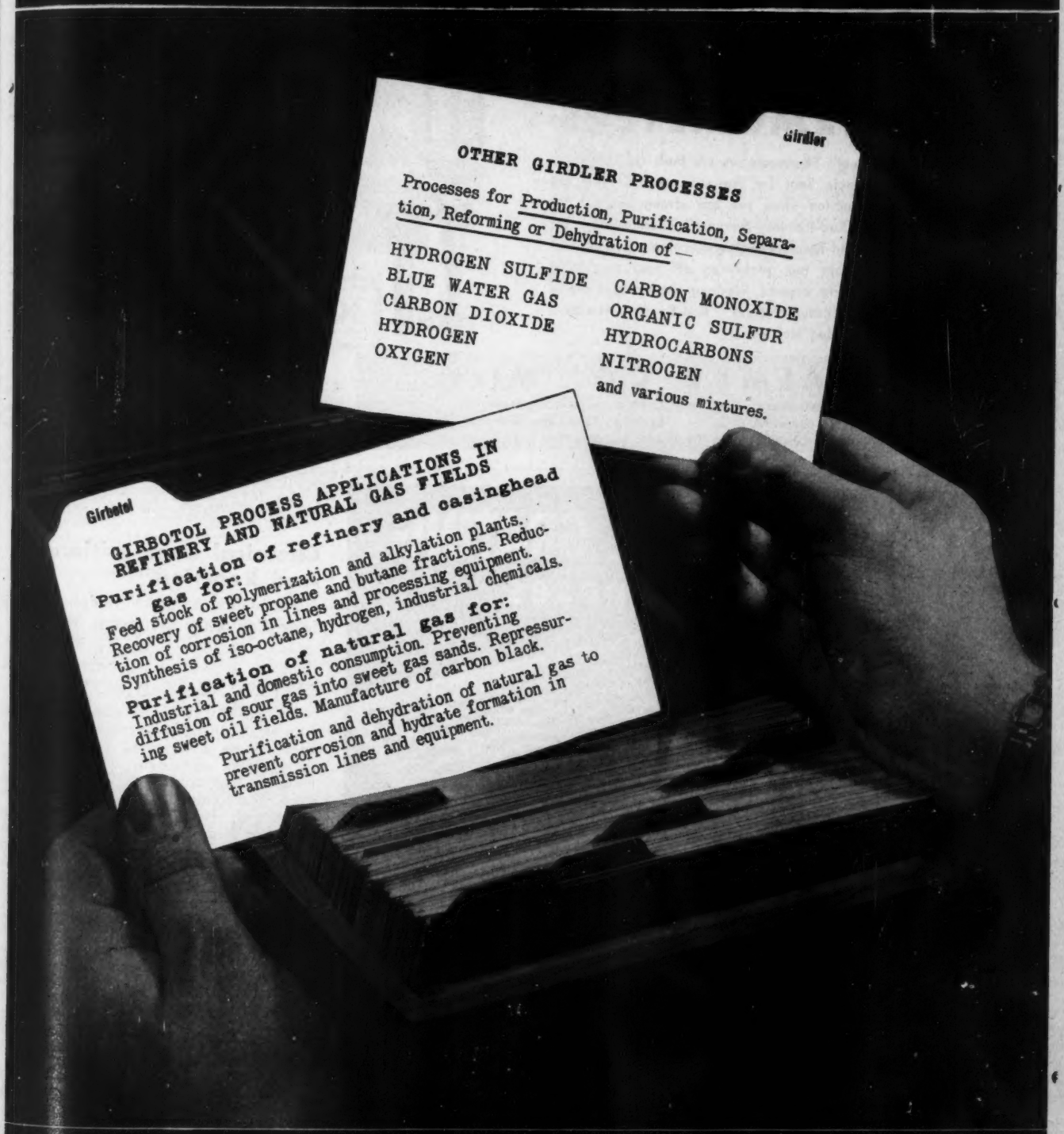
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accurately determined by a method presented in an earlier article by the author. The method has been standardized and used in laboratories throughout the world, under pressure conditions ranging from high vacua to several hundred pounds per square inch and in apparatus modified to suit various requirements. Detailed dimension drawings are presented of a simple unit for the purpose which may be constructed by any glass blower, since slight deviations have sometimes resulted in difficulties and inaccuracies in operation. The various factors are discussed with relation to the technique of utilization, and the vapor-liquid data of twenty-six different binary systems are reported.

Determination of High Pressure Vapor-Liquid Equilibria. The Vapor-Liquid Equilibrium of Benzene-Toluene, J. Griswold, D. Andres, and V. A. Klein, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 223-40.

The development and construction of a simple, rugged, and dependable apparatus for determining vapor-liquid equilibria is described. The apparatus is constructed entirely of metal and can be used for any non-corrosive system up to its critical pressure and temperature. Difficulties inherent in a method and apparatus for determining equilibria under pressure are reviewed. Construction of the apparatus is given in some detail, and the operating procedure is outlined. Using the apparatus, the authors took data on the system benzene-toluene, which was chosen because pure materials were readily obtainable and the behavior of the system is that of a normal binary hydrocarbon solution. Equilibrium diagrams are given for pressures up to 500 pounds per square inch gage.

Chemical Compositions And Reactions

Petroleum Acids. V. Aliphatic Acids from California Petroleum, W. A. Quebedeaux, G. Wash, W. O. Ney, W. W. Crouch, and H. L. Lochte, *Jour. Am. Chem. Soc.* **65** (1943) pp. 767-70.

By careful and extensive fractionation of California petroleum acids and their esters a series of 720 fractions of esters was obtained. Curves of ester fraction number plotted against boiling point and against index of refraction are presented. By studying various series of ester fractions with low index of refraction and with essentially constant boiling point the following aliphatic acids were isolated and identified: 2- and 3-methylpentanoic and n-hexanoic acids; 2-, 3-, 4-, and 5-methylhexanoic and n-heptanoic acids, and n-octanoic and n-nonanoic acids. No evidence for the presence of 2,2-dimethylpropanoic or 2-methylbutanoic acid could be found.

Petroleum Acids. VI. Naphthenic Acids from California Petroleum, W. O. Ney, W. W. Crouch, C. E. Rannefeld, and H. L. Lochte, *Jour. Am. Chem. Soc.* **65** (1943) pp. 770-7.

Through the use of a number of fractionation procedures in a continuation of the study of acids from California petroleum, the following naphthenic acids have been isolated and identified

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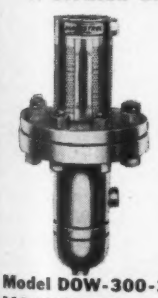

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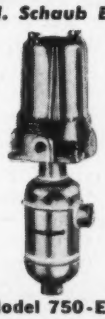

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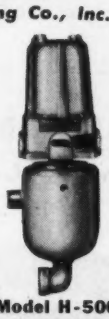

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Manufacture: Processes and Plant

Liquid-Liquid Extraction, O. Bergelin, F. J. Lockhart, and G. G. Brown, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) 173-200.

The increasing importance of extraction as a means of separating liquid components has increased the need for reliable design data, not only with respect to the particular extraction unit but also with regard to the physical properties of the liquids used. After a preliminary study of several ternary liquid systems, the authors chose the system tetrachlorethyleneisopropyl alcohol-water for study. Physical properties of the substances and their solutions were determined, as well as the equilibrium relationships of the system at 77° F. The extractor used was a horizontal tube operated with countercurrent flow of the fluid, and for transfer of isopropyl alcohol from a tetrachlorethylene phase across a known interfacial area to a water phase. The mass velocity of each phase was independently varied over a wide range and the mass transfer rates were determined. The two phases were forced through the extractor under pressure, being kept in separate layers by their density difference. The effect of the velocities of the phases upon flow conditions within the phases was shown by photographs. It is impossible to estimate the turbulent characteristics of flow by any orthodox use of the Reynolds number when two fluid phases are present in an apparatus since the velocity distribution in one phase is determined by the flow properties of both phases. The unusual variations in the transfer coefficient may be accounted for by the change in the velocity distribution within each phase. When the mass velocities of the phases are equal in magnitude, the interfacial velocity approaches zero, which creates a stagnant film in each phase and aids in the accumulation of foreign materials at the interface. At mass velocities of equal magnitude the transfer coefficient passes through a minimum point in the curves of K versus water-phase velocity and through an inflection point in the curves of K versus tetrachlorethylene-phase velocity. Within certain regions of velocity of one phase it was found that the mass-transfer coefficients can increase with increasing velocity of the other phase, while within other regions of velocity of one phase the coefficients decrease or go through a maximum or minimum with increasing velocity of the other phase. The effects of phase velocity as shown in the horizontal tube extractor offer a

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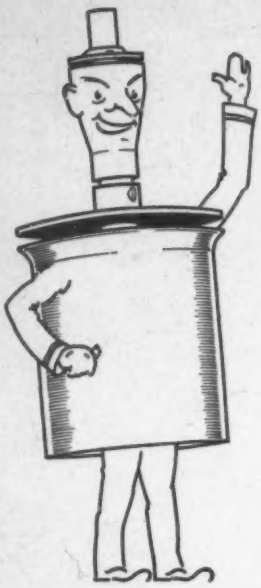

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possible explanation of the apparently contradictory data found in the literature.

Measurement and Control of Process Variables, Chem. and Met. Report, *Chem. and Met. Engr.* **50** (1943) pp. 97-144.

Tremendous progress has been made in the design of instruments for the measurement and control of process variables. The report is an attempt to clarify automatic control theories for the user rather than for the engineer of the instrument manufacturer, to review as many as possible of the process variables ordinarily encountered and to show the principal means for measuring and controlling each one, and to consider the relation of control to process design. The symposium includes articles on the fundamental principles of automatic control on instruments for measurement and control, a glossary of instrumentation terms, a consideration of the next decade in industrial instruments, a study of control in plant design, a discussion of control valve characteristics, a comparison of pneumatic and electric control, and a discussion of the progress in instrument application.

Cost of Pressure Vessels and Pressure Fractionating Columns, F. C. Fowler and G. G. Brown, *Trans. Am. Inst. Chem. Engrs.* **39** (1943) pp. 231-54.

The authors give data for estimating the cost of pressure vessels and plate fractionating columns. The cost of the column is broken down into vessel shell, bubble trays, platform, ladders, and handrails, insulation, and freight. Charts are given for estimating the cost of handholes, manholes, nozzles, couplings and tray supports. A procedure is given for estimating the cost of insulation.

Wartime Chemicals from Natural Gas, G. Egloff, *Jour. Inst. Petr.* **29** (1943) pp. 124-34.

Natural gas is consumed at the rate of over 2.6 trillion cubic feet per year. The U.S.A. has proved reserves of 85 trillion cubic feet and another 85 trillion cubic feet as potential reserves. The yearly consumption of natural gas is equivalent in fuel value to 100,000,000 tons of coal or over 500,000,000 barrels of fuel oil. Propane can be used to break in airplane engines, and has wide commercial application as a refrigerant and solvent. Isobutane is the key hydrocarbon in the production of aviation gasoline by alkylation. Normal butane is isomerized to isobutane. Isopentane is used in aviation gasoline because of its 91-octane rating. Propane-butane fractions from natural gas, when subjected to high-temperature cracking, produce ethylene, propylene, butylenes, and butadiene. Normal butane is converted into butadiene in ore or two stages by catalytic means at high temperature. The polymerization process of making aviation gasoline blending stock has been largely replaced by the alkylation process, in which isobutane is alkylated by butylenes in the presence of sulphuric or hydrofluoric acid catalysts. The resulting alkylate ranges in octane value from 91 to 96. Ethylene can be alkylated with isobutane to give neohexane having an octane rating of 94. An important aviation blending fuel of a different type is cu-

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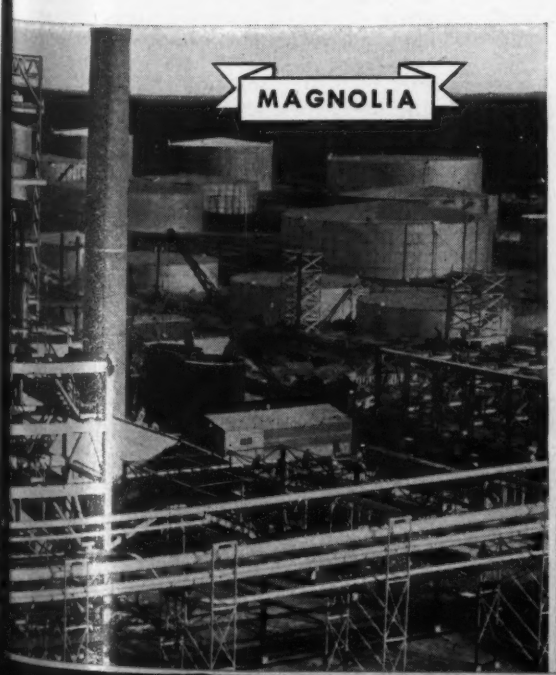

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mene, produced by the alkylation of propylene and benzene in the presence of solid phosphoric acid. Synthetic rubbers are reviewed briefly by the author. The production of acetylene from natural gas is considered. The production of carbon black from natural gas is reviewed. In 1940 369 billion cubic feet of natural gas were converted, yielding 285,000 tons of carbon black. Natural gas is an important source of high explosives. Hydrogen from it is combined with nitrogen to make ammonia. Natural gases contain hydrogen sulphide. Several commercial units are producing sulphuric acid from hydrogen sulphide or elemental sulphur produced from natural gas. Nitroparaffins from natural gas may well develop into one of the newest and most valuable of high explosives. Anaesthetics can be made from natural gas. Cyclopropane, produced from propane or propylene, is one of the most valuable. Olefins from natural gas are used as fruit ripening agents and for inducing accelerated plant-growth. Ethylene and propylene stimulate potato growth. The German Botanical Society reports that up to a 100 percent increase in the yield of potatoes can be obtained when the seeds are treated with ethylene gas. Russian researchers on butylene gas show a stimulating effect on the maturing time of such trees as walnut, peach, apple, cherry, plum, apricot, and pear. The trees are surrounded by tents and butylene is passed into the tent in about 1 part per 100,000 parts of air. The treatment period is 1 to 2 hours. Natural-gas hydrocarbons are used as basic materials for the synthesis of plastics after forming olefins. A chart is given showing the compounds and plastics derived from ethylene, propylene and butylene.

Oil—An Additional Basic Material for the British Plastics Industry, G. Tucendhat, *Jour. Inst. Petr.* **29** (1943) pp. 89-97.

The author reviews the petroleum industry as a source of raw materials for the plastics industry. Before the war the total production in Great Britain, U. S. A., and Germany was estimated at not exceeding 200,000 tons of plastics per annum, of which England and the U. S. A. produced 135,000 tons. Much larger quantities of plastics will have to be produced, and therefore larger quantities of raw material will be consumed. Phenol, styrene, acetone, alcohols, and many other substances are being produced from petroleum in rapidly increasing quantities. Other new raw materials are offered by the petroleum industry, and new chemical products and plastics will be developed from them.

Products: Properties And Utilization

Piston-Ring Scuffing as a Criterion of Oil Performance, G. H. Keller, *S.A.E. Journal* **51** (1943) p. 125.

Aircraft-engine lubricating oils were tested in a single-cylinder air-cooled aircraft engine. Power, speed, fuel-mixture, temperature, oil supply, detonation, and cylinder, piston, and ring design were under control, and all except cooling conditions and oil supply were held constant. Conditions of greater severity were imposed by decreasing the

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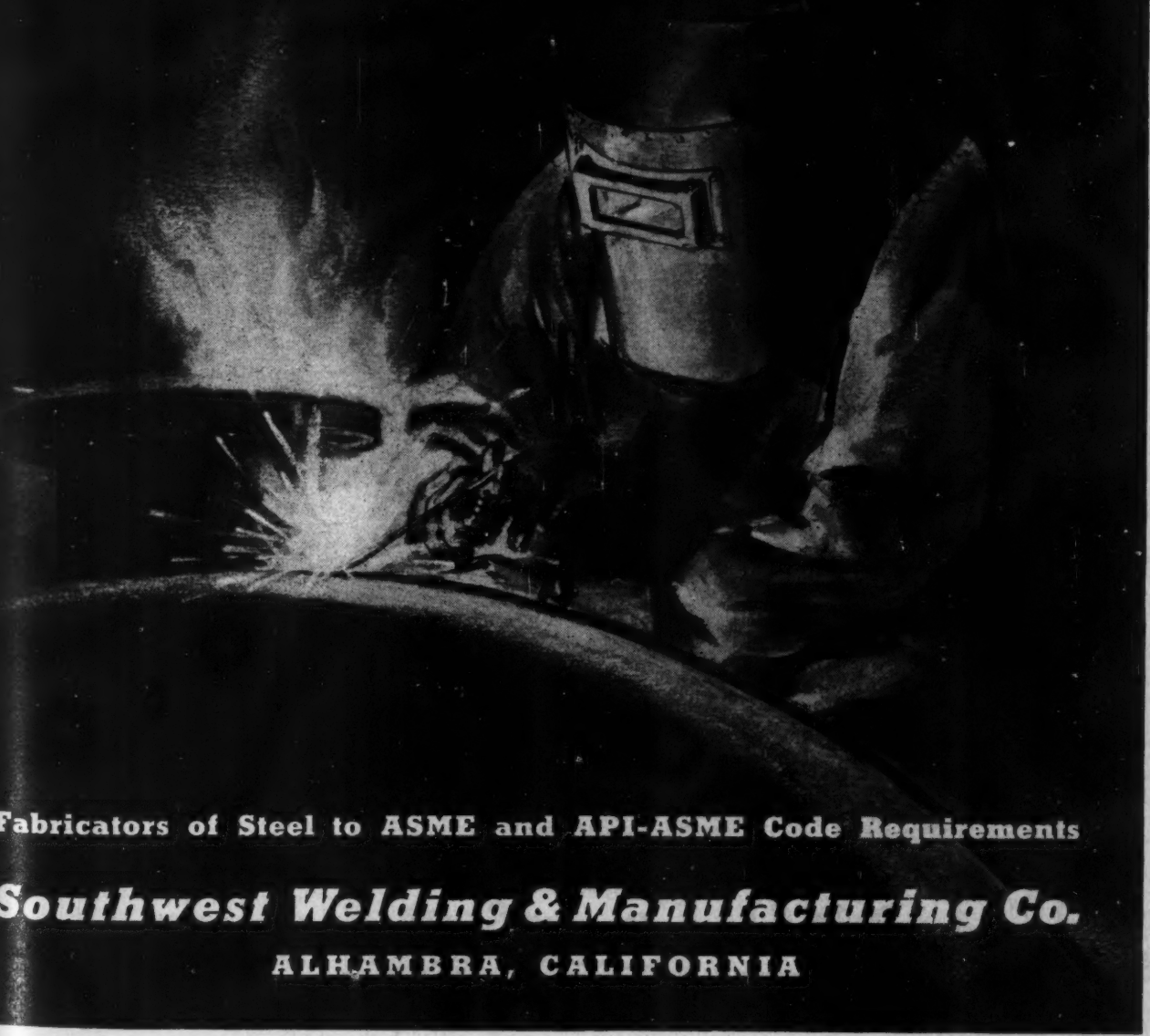

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Amsco Alloy Proved a "Natural" for Tube Supports in Petroleum Stills

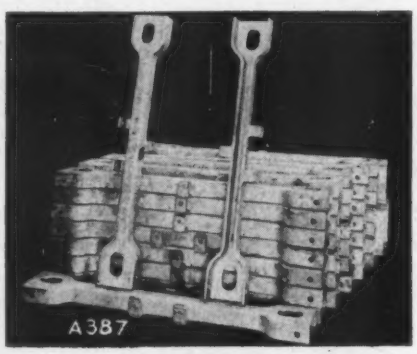
The corrosion and high temperatures encountered in petroleum stills rapidly deteriorate tube supports and other ordinary steel or iron castings. The life of tube supports was a subject of much importance in the early years of cracking stills. This condition created a natural field of application for Amsco Alloy, which was developed expressly to withstand high temperatures and corrosion for the longest possible periods.

Well known to refinery operators is Amsco Alloy F-10, a grade containing 26-28% chromium and 10-13% nickel. This alloy has proved ideal for tube supports, having substantial load-carrying strength at temperatures up to 2000° F., combined with high resistance to sulphur corrosion. Tube supports and other oil still castings of the F-10 grade have not only earned their price in length of service; they have shown the greatest ultimate economy.

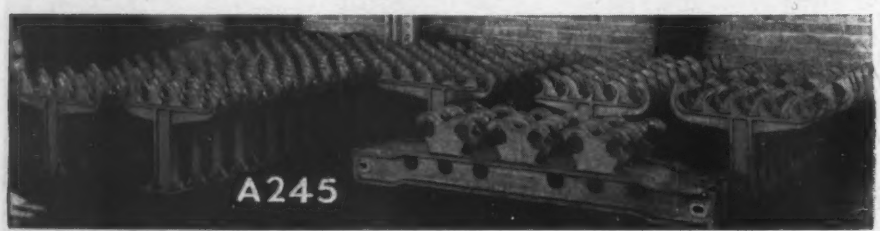
Hundreds of tons of Amsco Alloy tube supports, in a number of designs, are at work in refineries in all the major fields. Other refinery applications include tube sheets, hangers, liners, guide hooks, damper doors, burner nozzles and bars.

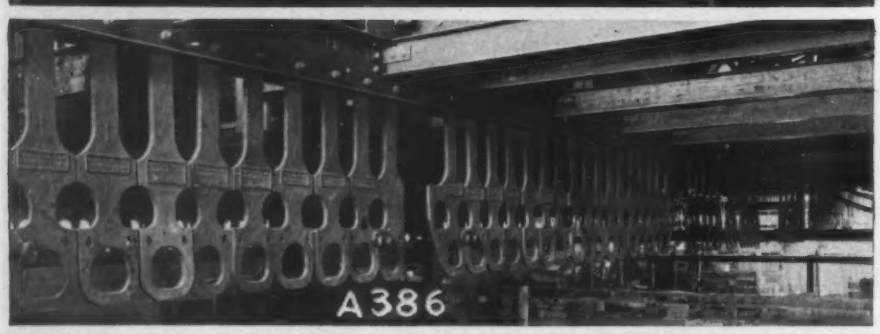
The use of Amsco Alloy not only prevents interruptions in the highly essential flow of petroleum products, it also conserves metals in a most practical way.

Bulletin No. 108, sent on request, contains complete information on Amsco Alloy.



A-387 Amsco design of tube supports. A-245—Wall tube brackets and intermediate supports. A-386—Tube hangers in radiant section. (S.O. Ind. patent)





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cooling and the supply of oil to the piston and cylinder wall. The engine was run for 5 hours at cruising power for each oil test. Good oils completed the periods with small oil consumption. The oil consumption for the poorer oils was so high that the test had to be terminated before the end of the 5 hour period. After each test the rings and piston were examined and the oil rated in accordance with ring scuffing and general wear and consumption of oil. Comparison was made between laboratory analyses of the new and the used oils, but no trend of change was found that permitted rating the oils in the same order as they were rated by the appearance of the rings and piston in the test.

Catalysis in the Oxidation of Lubricating Oil, R. G. LARSEN AND F. A. ARMFIELD, *Ind. & Eng. Chem* **35** (1943) pp. 581-8.

The most important environmental factors affecting the oxidation stability of an oil in an engine are temperature and catalysis. The effect of temperature on oxidation stability is fairly well understood. Methods of testing oxidation stability are briefly reviewed, including those in which a study of catalysis has been made. The catalytic effect of iron, copper and lead in the bulk and dissolved form on three oils broadly representative of those obtainable from Pennsylvania, Mid-Continent, and California crudes was studied in detail. It is concluded that the variations in catalytic susceptibilities of the oils, as well as the variations of catalytic activities of the metals with concentration, are so great that no specific catalyst can be used in laboratory oxidation tests unless correspondence with engines is first well established. In addition, the catalytic effect of engines on oils was investigated. It was found that the oil insolubles (called "crankcase catalysts") that accumulate in engine lubricants are extremely active catalysts. This catalytic activity resides in the metallic components, particularly the halides of iron. The data secured in the work are presented in considerable detail in tabular and graphical form. All of the oils were found to be quite susceptible to catalysis by very low concentrations of soluble copper and iron. At low concentrations (below 5 p. p. m.) copper is more active than iron; above this concentration iron is the more active. The naphthenate salts generally show a maximum in catalytic activity that is particularly pronounced in the case of lead and copper.

Oxidation - Corrosion of Lubricating Oils, C. L. POPE AND D. A. HALL, A.S.T.M Bulletin No. 121 (1943) pp. 25-8.

An accelerated oxidation-corrosion tester for lubricating oils is described. It can be used to predict the useful life of an oil as a means of studying blends of new and used oil, as a means for determining the corrosion of ferrous materials in the presence of moisture, and to determine the point in the useful life of an oil at which corrosion products are first formed. The results obtained by use of the test unit correlate well with the service life of oil. 250 c.c. of oil, together with a test strip of materials used in the particular machine constructed, are placed in a tightly closed 400 cc. beaker. Heat is applied by means of the constant-temperature

How about your crude?

If you are a refiner still making peacetime products the following statement is no news to you:

> Generally firm tone continuing in petroleum markets reflects the fact that *many refiners are in difficulties over the question of adequate crude supplies*

That is from Keith Fanshier's oil page in the Chicago Journal of Commerce, April 30, 1943

Further down in his column Mr Fanshier writes:

> No question about it; high octane aviation gasoline [100-octane] is needed in staggering quantities and ever greater ones

Refineries that can make 100-octane gasoline, any component of it or any other war product *must* have adequate crude supplies—and they do

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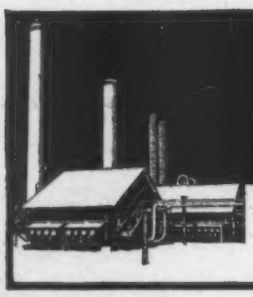
"The life and soul of science is its practical application."
— Lord Kelvin

1743-1794
Antoine Laurent Lavoisier, while a notable chemist, devoted considerable attention to physical problems of heat. Some of the earliest thermochemical research was credited to Lavoisier.

Lavoisier's well-known experiments with combustion have been important contributions to heat applications. He made notable experiments with oxygen, to which he gave that name.

Pioneering physicists made scientific discoveries. Research and constructive engineering applied these discoveries to industrial usefulness. Alcorn, pioneer in heating for petroleum processing, places at your disposal 19 years' continuous engineering research and successful experience in providing efficient, economical heaters for the diverse, ever-changing demands of oil refining.



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oil bath, the oil is agitated and treated with moisture and oxygen. In testing turbine oils the test strip was made of steel wound with a few turns of copper wire. In testing diesel oils cadmium and lead-copper assemblies were used. The reaction temperature used was 100° C. Oxygen saturated with water vapor was used at the rate of 3 liters per hour. The volatile oxidation products were returned to the beaker by means of a reflux condenser. Samples were inspected for change of color and for corrosion of the test strips every 24 hours, and small samples were withdrawn for the determination of the neutralization number and the interfacial tension against distilled water. After 96 hours of operation any given sample was placed in one of three groups: (1) oils decreasing less than 5 dynes per centimeter interfacial tension; (2) oils losing more than 5 dynes but having greater than 15 dynes per centimeter interfacial tension; (3) oils having less than 15 dynes per centimeter interfacial tension. Duplicate tests on the same oil resulted in identical corrosion records and gave oxidation stabilities that differed by not more than 10 percent.

A Note on "Oiliness" and Surface Roughness, J. J. BIKERMAN, *Jour. Soc. Chem. Ind* **62** (1943) pp. 41-2.

An empirical relationship has recently been found between the time required to separate two plates immersed in a lubricant and the force used for the separation. It was believed to be connected with the "oiliness" of the lubricant. The present note shows that this relation can be deduced from hydrodynamical considerations and utilized for estimating the roughness of the contact surfaces of the plates. The modern tendency is to explain "oiliness" as caused by molecular orientation, molecular interactions, etc. Since sliding friction is due to surface roughness, a relation between the "oiliness" of a lubricant and its influence on the effective surface roughness may be expected. Although a general proof of the existence of this relation cannot be given as yet, it is possible to show in a particular example that when it is intended to measure "oiliness" the experiments may in fact give a measure of roughness.

Limitations of Viscosity Index, G. J. C. VINEALL, *Petroleum* (London) **6** (1943) p. 41.

The author contends that great damage has been done by the introduction of the viscosity index system to petroleum science. He feels that the adoption of the viscosity index scale with the 100 maximum has caused a complacency with respect to the viscosity-temperature characteristics of the existing oils and has given the impression that an oil with viscosity index of 100 is the optimum to be desired. Scientific effort that should have been devoted to explanation of such qualities as film strength or the synthesis of more satisfactory lubricants has been sidetracked to the examination of small differences in viscosity between members of the present lubricating oil family of very imperfect materials. The author considers that the perfect lubricant should lose in viscosity on heating only to such an extent as would compensate any reduction in clearances caused by

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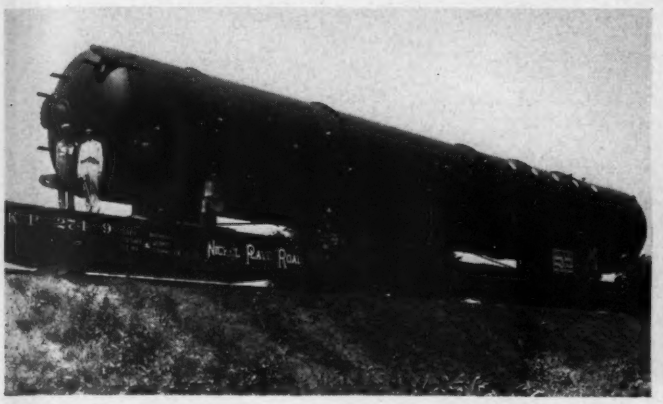
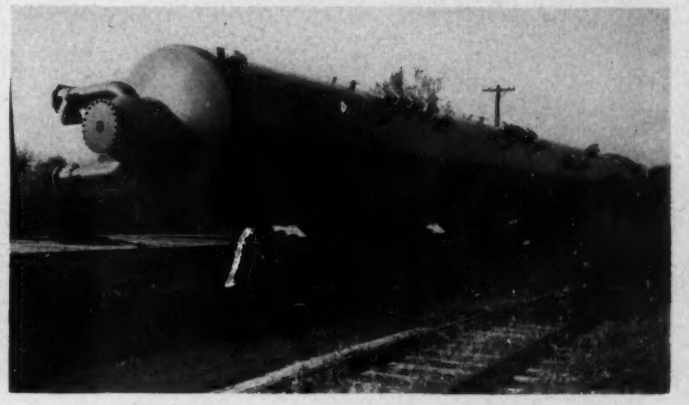
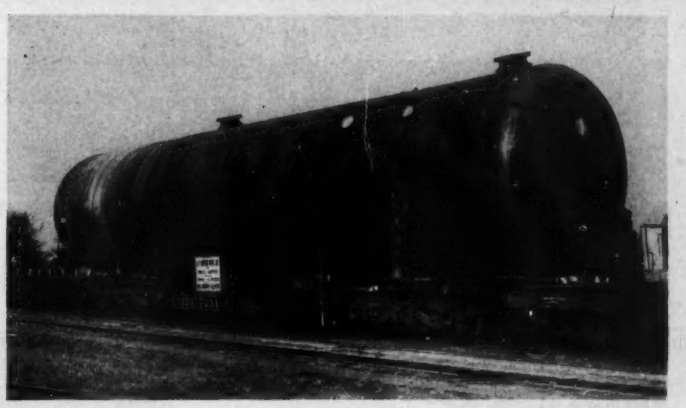
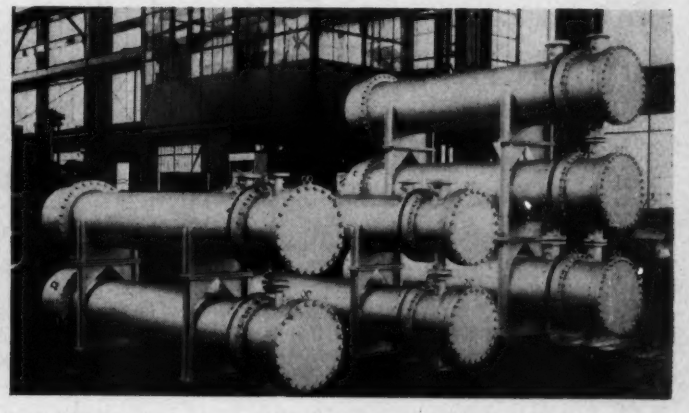






BUBBLE TOWERS - PRESSURE VESSELS - TANKS, API, ASME



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the heating of the lubricated surfaces. The best present oils fall far short in this respect. The difference in loss of viscosity between high viscosity index oils and low viscosity index oils is relatively small when compared to the total loss in viscosity of either oil between any two temperatures. The author feels that much of the recent work on viscosity and viscosity index measurement seems to be rather like taking surgical instruments to chop firewood.

Viscosity Measurement and Viscosity Index, J. C. CRAGG AND E. A. EVANS, *Jour. Inst. Petr.* **29** (1943) pp. 99-123.

The recent appearance of viscosity index in government specifications in Great Britain makes its estimation a matter of considerable importance to the industry. It becomes necessary, therefore, to see clearly how accurately viscosity can be determined, and what effect errors have on the calculated viscosity index. Numerical deviations in viscosity index created by errors in viscosity determination are presented in tabular and graphical form. From a study of the accuracy of the Redwood viscometer and the conversion of Redwood seconds to kinematic units the author concludes that the Redwood viscometer does not give the requisite degree of accuracy for the calculation of viscosity index, except possibly for oils of relatively high viscosity. The specifications of the British standard U-tube viscometer are given, and an effort is made to summarize and assess the errors probable in its construction and use. Typical results secured in the use of the instrument are given. A table is given showing the viscosity determinations of the same oil by five different laboratories in principal countries. A tabulation of viscosity determination by four reputable laboratories in the U. S. A. while investigating the relationship between kinematic viscosity and Saybolt Furol viscosity for the A.S.T.M. is included. Calibration of viscometers is considered in some detail. Errors introduced by the result of the use of secondary standards are discussed. A bibliography of 17 references is included.

An Improved Meter for the Measurement of Gas Flow Rates, W. G. APPLEBY AND W. H. AVERY, *Ind. & Eng. Chem., Anal. Ed.* **15** (1943) pp. 349-50.

An improved meter for the measurement of gas flow rates is described that does not require a separate calibration for each kind of gas as does an orifice meter, nor is it subject to the disadvantages of a wet displacement type meter. A drop of mercury is trapped in the flowing stream of gas, and the time required for the drop of mercury to move between two fixed points is measured. The instrument, with proper construction, can be used either under vacuum or under pressure. Typical calibration curves for hydrogen and for nitrogen are given. Details of construction of the meter are included.

Fire Fighting

Walter Kidde & Company, Belleville, New Jersey, have issued an illustrated 16-page manual "How to Teach Fire Fighting," which is designed to aid in instructing workers in fire-extinguishing techniques. It describes the classification of various types of fires, the kind of extinguisher best suited to each, and the methods of setting up demonstrations in order to teach the proper use of each type of extinguisher.

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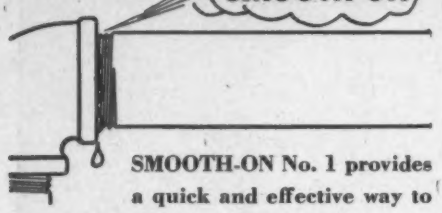

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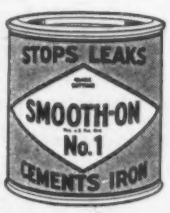

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☆ BUSINESS NOTES ☆

Thad Smith, Jr., Houston Representative for Bridgeport

Thad Smith, Jr., recently was appointed Houston district manager for Bridgeport Brass Company, Bridgeport, Connecticut, according to an announcement of Austin Zender, general sales director of the company. Smith will have his headquarters at the company's warehouse office at 2216 Walker Avenue in Houston. He has been associated with the copper and brass business in Texas for the past seven years.

THAD SMITH, JR.

P. R. Greenman Joins Ludlow Valve Company

P. R. Greenman has joined Ludlow Valve Manufacturing Company as industrial sales engineer in the Chicago territory. He is a mechanical engineer and designer of wide experience in power plant and oil refinery equipment. His early work, following graduation from the University of Illinois, was a designer of valves, tools, fittings and special machinery for the Detroit Lubricator Company and the American Valve Company. Later connections were with Wright-Martin Aircraft Company as tool development engineer; as plant engineer with the Power Specialty Company of Danville, New York; and from 1922 to 1934 as resident engineer with Foster Wheeler Corporation in Chicago. In January 1935 Greenman joined Favelle-LeVally Corporation as resident engineer in Chicago, returning in July, 1937, to Foster Wheeler Corporation as Cincinnati district manager. He now is handling the industrial line of Ludlow Valve Manufacturing Company, working out of the Chicago offices.

P. R. GREENMAN

Osterstrom Joins Velsicol Corporation

R. C. Osterstrom who, for the past 20 years has been connected with The Pure Oil Company, has become vice president in charge of manufacturing for Velsicol Corporation, 120 East Pearson Street, Chicago. He will divide his time between Chicago and the Velsicol plant at Marshall, Illinois.

Osterstrom's business career has always been in connection with the petroleum industry. After leaving school, he joined Gulf Refining Company at Bayonne, New Jersey, and later at Port Arthur, Texas. During the first World War he served in the United States Navy. In 1919, he became affiliated with Sinclair Refining Company at East Chicago, Indiana, as assistant to the chief chemist. In 1923 he joined The Pure Oil Company as chief chemist, subsequently becoming executive assistant to the vice president in charge of manufacturing. Recently, he was located in Toledo, Ohio, as manager of The Pure Oil Company Refinery there.

R. C. OSTERSTROM

Bedell Chief Engineer For Graver Company

A. E. Bedell has been appointed chief engineer for Graver Tank & Manufacturing Company, East Chicago, Indiana. He will be in charge of all engineering and development covering all divisions of the company. Mr. Bedell has had wide experience in construction of refinery equipment. His headquarters will be in Chicago.

A. E. BEDELL

Dow Chemical Forms Development Division

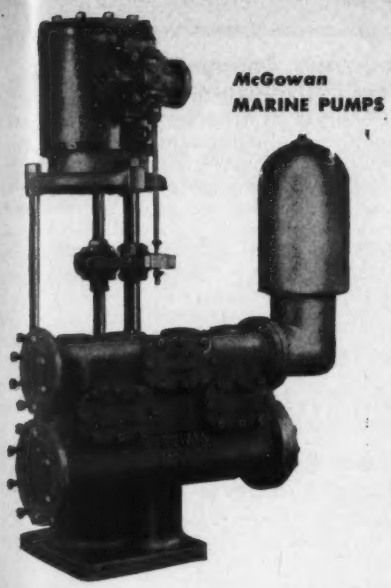
The Dow Chemical Company has organized a development division, one of whose major purposes will be to study and further application of standard and new products to industry in the post-war world. D. K. Ballman, who has been in the Dow organization for eight years, has been placed in charge of this new division, which will have headquarters at Midland, Michigan.

D. K. BALLMAN

The division will be staffed by a group of experts, selected for their full technical knowledge of Dow products and specific industries. The company has long been doing this sort of work under separate divisions. Now its efforts will be coordinated under one head.

"Dow Chemical Company has a highly diversified line of more than 500 chemicals which have proven to be indispensable to industry both in peace and war," Ballman said. "Also an immense number of new products have been synthesized, many of which will without question prove to have extremely important applications. The wartime uses of the former are far from exhausted, and many of the latter have enormous potentialities for America's all-out effort for victory.

"The new division, which will take the initiative in contacting the technical men in other industries will seek to develop a technical consulting service. We will call the technicians' attention to



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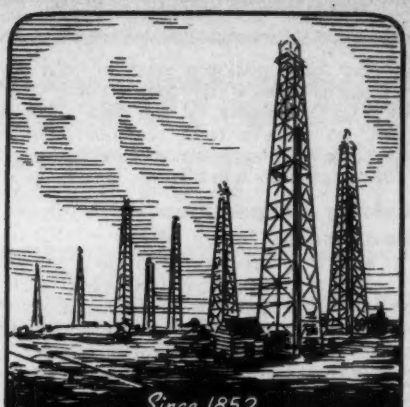

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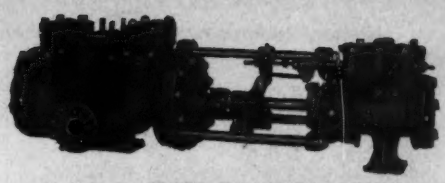

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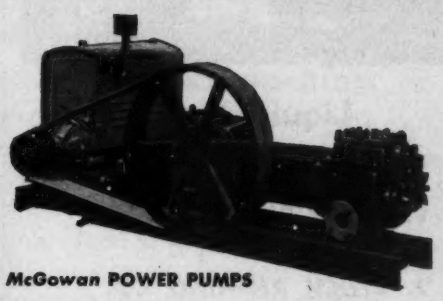

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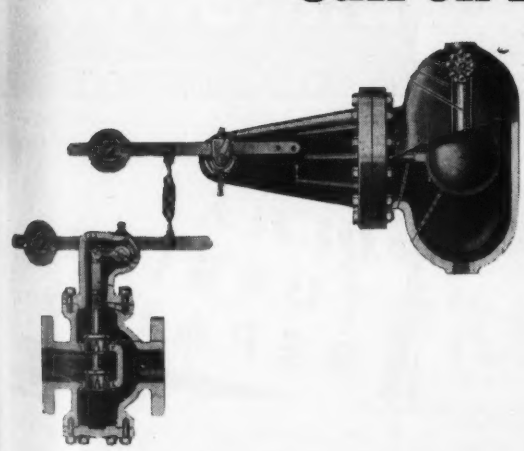

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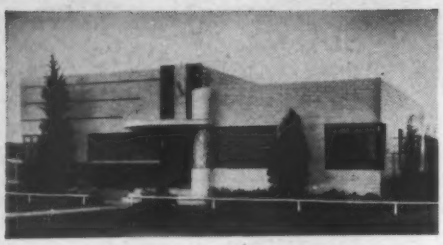

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WANTED: REFINERY OPERATORS who have had stillman or supervisory experience in modern oil refineries. Give refining background and complete experience record. Location Houston, Texas. Send reply to: Box 707, Petroleum Refiner, Houston, Texas.

Ingersoll-Rand air compressor 650 C.F.M. and one A.C. 75 K.W. Generator set complete with switch board and exciter.

356 West North Street,
Indianapolis, Indiana

FOR SALE—2 Belt Driven Worthington CO_2 Compressors, 1200 lb., single three stage 10" x 6¼" x 3" x 18", 172 Cu. Ft. Displacement at 110 r.p.m. Subject to prior sale.

SIBONEY DISTILLING CORPORATION
1021 North Penn Street
Philadelphia, Penna.

WANTED—Mechanical engineer between 30 and 45 or man with suitable mechanical training equivalent as inspector for chemical plant equipment. Should be familiar with pressure vessels, pipe lines, pumps, storage tanks and similar equipment. Good opportunity for advancement. Rapidly expanding plant located in Detroit area manufacturing important war chemicals. Applicant must be qualified to accept responsibility. Also must qualify under WMCES. Write giving full details including education, work experience, references, and salary desired. Address replies to Box 606, c/o Petroleum Refiner, Houston, Texas.

present and possible uses of old and new products which may solve their wartime problems. If we find that we have no answer to a feasible proposition, we will at once put our research laboratories to work on it."

Carrier Corporation Reallocates Sales Staff

Carrier Corporation, Syracuse, New York, has made a reallocation of the duties of the personnel of its marketing division. Among the new assignments are: L. L. Lewis, technical adviser to the marketing division in air conditioning; W. F. Jones, to a similar capacity in centrifugal refrigeration; O. W. Bynum transferred from the Southern region to manager of the marketing division, which has been eliminated and its territory divided between the Eastern and Central regions.

M. T. Firestone was named liaison representative of the Eastern region with headquarters at the home office and B. R. McCumber will hold similar duties for the Central region. J. A. Gazalle will become regional dealer manager at Chicago.

Brown Instrument Company Has Two New Vice Presidents

George M. Muschamp and Paul L. Goldstrohm have been appointed vice presidents of The Brown Instrument Company, a subsidiary of Minneapolis-Honeywell Regulator Company.

Muschamp will be vice president in charge of engineering and Goldstrohm will be vice president in charge of production. Both posts are newly created.

Muschamp, who is 34 years old, has been with the Brown engineering department for 12 years and has been in charge of engineering for the past 3 years. He directed the development of a number of Brown electronic devices, including the electronic potentiometer for controlling industrial temperatures and the Flight Recorder, which is being widely used in testing war planes.

Goldstrohm, who is 41, recently celebrated his twentieth year with the company. He has been serving for the past 2 years as assistant general manager and formerly was the company's purchasing agent.

Dresser Manufacturing Company Names Two New Officials

Norman Chandler of Los Angeles has been made a member of the board of directors of Dresser Manufacturing Company, and R. E. Reimer, Bradford, Pennsylvania, was named secretary and treasurer.

Chandler is president and general manager of the Los Angeles *Times*. He is also a director of Pacific Pump Works, Huntington, California, one of Dresser's subsidiaries.

Reimer has been with the company since January, 1929, and has been treasurer since May, 1932.

Snetsinger to Direct Magnetrol Marketing

E. J. Snetsinger has been appointed general manager of Magnetrol, a newly organized division of the Fred H. Schaub Engineering Company, Chicago, manufacturers and designers of condensate return and boiler feed equipment. This new division will assume complete control of the manufacture and sale of Magnetrol automatic liquid-level control units.

Cochrane Announces New Distributors

Cochrane Corporation, Philadelphia, announces appointment of the Metrol Company as flow meter representative for the Detroit territory. Metrol Company is located at 2970 West Grand Boulevard, Detroit, and will also handle Hays combustion control and instruments, Reliance gauge columns and Wilson tube cleaners.

The company also announces the appointment of Bushnell Controls and Equipment Company, 117 West Ninth Street, Los Angeles, for the direct sale of flow meters in California, Western Nevada, and Arizona.

Vapor Recovery Makes Changes in Sales Force

Vapor Recovery Systems Company, Compton, California, announces the following appointments as sales engineers:

Clifford T. Stanhope is in charge of the Eastern office and warehouse at 30 Church Street, New York.

Frank M. Holloway, formerly eastern

SAVE LINERS
by using
NON-SCORING
Segmental
"BAKORINGS"

- As the plastic material of these rings is practically self-lubricating, temporary loss of lubricant will not affect the life of the piston rings or the liners.
- Grit and scale become embedded in the plastic and do not scrape liner as with metal rings.
- Basic material made by General Electric Co.
- Proved by leading companies to give lower service cost per hour.

QUICK DELIVERY . . . WRITE FOR FOLDER AND PRICES.

BAKORING
INCORPORATED
1020 HOUSTON, AVENUE
HOUSTON, TEXAS

QUICK TURBINE REPAIRS

If you need dependable Turbine repairs **in a hurry,** call us. We are completely equipped to repair and dynamically balance turbine rotors and any High Speed rotating elements in our modern shops.

25 Years Successful Experience

GULF ENGINEERING CO., INC.
"Service, Not Promises"
307 M. & M. BUILDING
HOUSTON, TEXAS
916 S. PETERS STREET
NEW ORLEANS, LA.

IF YOU WANT TO CUT DOWN ON RE-PACKING...BETTER TRY SEA RINGS!

● With virtually the entire production of J-M Packings and Gaskets needed for war, delivery on other than high-priority orders may be slower than in normal times. However, through increased capacity and round-the-clock production, every step is being taken to assure the fastest delivery possible under the present emergency.

It's not packing—it's* RE-packing *that's really expensive . . . that's why it pays in dollars and cents to use the best packing money can buy. J-M Sea Rings are that kind of packing.

They're custom-made to fit specific operating conditions. Entirely automatic, they seal on the work stroke, release on the return, thus reducing friction and wear on both packing and rod. During the past 25 years many engineers have accepted Sea Rings as the standard packing for reciprocating rods and plungers operating against steam, water, air, brine, oil, gasoline and many other fluids and chemicals.

For details on J-M Sea Rings and the complete line of J-M Packings and Gaskets, write Johns-Manville, 22 E. 40th St., New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville PACKINGS & GASKETS

THERE'S A DISTRIBUTOR NEAR YOU

CALAPOR

CAPTAIN PRODUCTS

INSULATIONS
LIGHT IN WEIGHT . . . EFFICIENT

SPECIALTIES
ADAPTABLE TO SERVICE

CALAPOR MANUFACTURING CO.

Office: Hibernia Building, New Orleans, La.
Factory: 5521 Clinton Drive, Houston, Texas

YOUR ANSWER for speeding wartime MAINTENANCE

Easy Way to Clean Heat Exchangers

When insulating deposits form on tubes . . . get rid of them QUICK! They may seriously impair operating efficiency of condensers, coolers, steam generators, reboilers, and other heat exchange equipment. Fast-working Oakite materials EASILY remove them . . . helping to restore normal heat transfer . . . returning units to service in double-quick time.

To remove scale and rust, treat system with solution of Oakite Compound No. 32. For sludge, use solution of recommended Oakite degreasing material. Insulating deposits are effectively loosened and easily removed . . . without disassembly or excessive shutdown time.

Complete Data FREE!

Without obligation, send for full information on how Oakite materials speed maintenance work . . . washing drums, stripping paint, salvaging equipment, etc. Write today!

OAKITE PRODUCTS, INC.
508 Thames Street, New York
Technical Service Representatives Located in All Principal Cities of the United States and Canada

OAKITE *Specialized* CLEANING

Buy Bonds for Victory

sales manager, will assume new duties as Southeastern sales manager with headquarters at New Orleans.

John L. Shaunty has been appointed manager of Mid-Continent Sales, distribution, and service. He will have complete charge of both Houston and Tulsa offices and warehouses.

Correction of Error In Advertising Copy

In the May, 1943, issue of PETROLEUM REFINER an advertisement of the Floridin Company was illustrated with a view of a solvent treating plant of Continental Oil Company, mistakenly labelled as a hydrofluoric acid alkylation unit.

We and the advertiser are now informed that no such unit is included in this plant and the advertisement will not appear again until a correct illustration is substituted.

Sonken-Galamba Changes Name to Refinery Equipment

W. C. Berry, president of the former Sonken-Galamba Supply Company, announced recently that this company will be known as Refinery Equipment Inc. hereafter. Berry said this step has been taken so that the organization's name may be more closely associated with the oil industry which it serves.

Under the new name, this company will continue to buy and sell complete refineries and carry stocks of reconditioned refinery equipment.

There will be no change in staff or officers. The company has headquarters at Tulsa, with branch offices at Kansas City, Kansas, and Kilgore, Texas.

D. D. Wile Joins Carrier Corporation

D. D. Wile has joined the engineering staff of Carrier Corporation, with headquarters in New York. He has a broad background in the fields of engineering and manufacturing. After completing his engineering courses at the University of Kentucky, he joined American Radiator Company as research engineer. After several years he went with Detroit Lubricator Company where he held the position of chief engineer of the refrigeration and air conditioning division. From 1937 until 1941, Mr. Wile was chief engineer of the refrigeration division of the Savage Arms Company. For the past two years he has been general plant manager of the Kellogg Division of American Brake Shoe and Foundry Company.

Quimby Pump Company Purchased by H. K. Porter

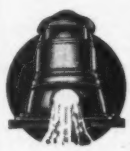
Purchase of Quimby Pump Company, with plants at Newark and New Brunswick, New Jersey, has been announced by H. K. Porter Company, of Pittsburgh.

Quimby Pump Company manufactures a full line of pumps including screw, centrifugal and rotex types, and will be operated as a division of H. K. Porter Company.

Retired Official of Petreco Concern Dies

L. J. F. Morison, who, for twenty years, was an official of Petroleum Rectifying Company of California, died in Los Angeles in April. He had been affiliated with the oil industry since 1910 except for a period during World

THE OLD WINDJAMMERS



The old "windjammers" were built to sail the heaviest seas that rolled. In fair weather or foul, with rare exceptions, they delivered their cargoes. It was sturdiness in build, skill in design and quality of materials that made them give such good service.

It is in a like manner that Layne Pumps and Well Water Systems are constructed:—sturdy, efficient—long lasting—and above all, reliable. Some have been in service for a quarter century. Later installations were designed and built to last even longer.

Such outstanding quality will make Layne Pumps and Well Water Systems first in choice for the post-war era. They will be chosen wherever large quantities of water must be produced at exceptionally low cost. Layne Pumps and Well Water Systems have been proven the world over—proven for basically sound quality, advanced engineering features, sturdiness in construction, unequaled efficiency and outstanding reliability.

For the duration the Layne Organization is, in addition to doing much urgent war work, endeavoring to keep present installations in repair and operating at top efficiency. If you wish literature, address, Layne & Bowler, Inc., General Offices, Memphis 8, Tennessee.

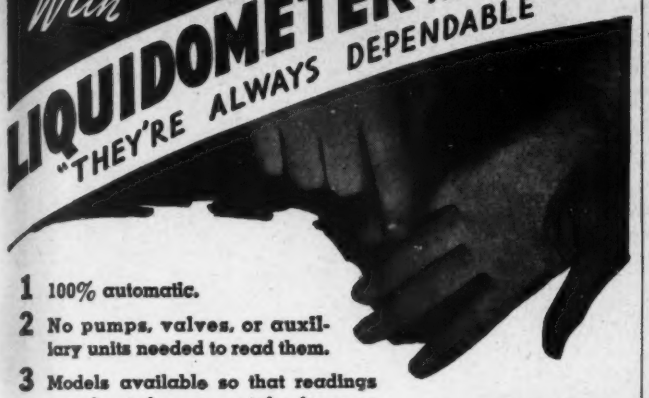
AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minnesota, Minneapolis, Minn. ★ International Water Supply Ltd., London, Ontario, Canada.

LAYNE
WELL WATER SYSTEMS
DEEP WELL PUMPS

Builders of Well Water Systems for every Municipal and Industrial Need

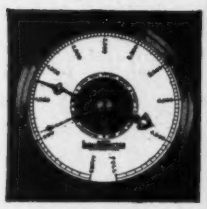
5 Reasons Why We Measure Our Valuable Stored Liquids With LIQUIDOMETER Tank Gauges

"THEY'RE ALWAYS DEPENDABLE"



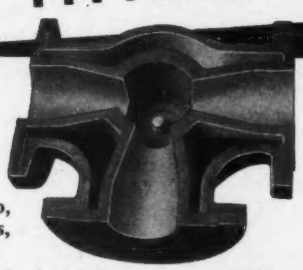
1. 100% automatic.
2. No pumps, valves, or auxiliary units needed to read them.
3. Models available so that readings can be taken remotely from or directly at the tank.
4. Accuracy unaffected by specific gravity of tank liquid.
5. Approved for gauging hazardous liquids by Underwriters' Laboratories and other similar groups.

Write for complete details



THE LIQUIDOMETER CORP.
39-14 SKILLMAN AVE., LONG ISLAND CITY, N.Y.

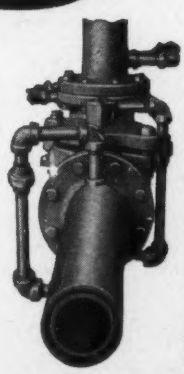
H & B JACKETED PIPE and FITTINGS



Insure Trouble-Free Service because . . .

1. Heating medium goes up to, but not through, the flanges, on both pipe and fittings.
2. Jackets go to flanges on both pipe and fittings, thus eliminating cold spots.
3. Drain plugs for any mounting position of fittings insure proper circulation and drainage of condensate if steam is used.
4. Valves are of plug cock type with special provisions for maintaining proper tension on the plug—without binding.
5. Pipe has heavy steel flanges, welded to both process pipe and jacket.

Write for complete information.



HETHERINGTON & BERNER INC.
735 Kentucky Avenue
Indianapolis, Indiana

Hetherington & Berner

"We'll bring 'em down..."

"if you'll send us the shells!"

Our boys will bring down the enemy planes with their ack-ack fire, if we will give them the guns and the shells. So, let's all stay on the job *every* day to keep the equipment, ammunition and supplies rolling off the production line. And let's lend *every* dollar we can spare for War Bonds. We can win—we *will* win!

THE GARLOCK PACKING COMPANY, PALMYRA, NEW YORK
Manufacturers of GARLOCK Packings, Gaskets and KLOZURE Oil Seals

Tulsa, Okla. Houston, Texas Los Angeles, Calif.

GARLOCK

YARWAY STRAINERS are *selling by the thousands* because they are better engineered for the service.

***"The Screen is the Thing"*—a high-grade, woven Monel wire screen that stops the dirt, lets fluids flow freely.**

Then too, purchasers like the *body finish—Cadmium plating inside and out* for protection against corrosion.

And last but not least, it is *"Easy to Clean"* having a steel blow-off bushing, precision machined with straight thread. Screen and bushing come out together—go back together, automatically aligning.

Six sizes, ½" to 2" for pressures up to 600 lb serve practically all strainer needs.

Sold by over 100 Mill Supply Houses. See your Supply House or write for Bulletin S-200.

YARNALL-WARING COMPANY
128 Mermaid Ave. PHILADELPHIA

War I when he served in a government position with the grain administration. In 1920 he joined Petreco as assistant secretary and was elected secretary the following year and retired in 1940 because of poor health. Morison was secretary-treasurer and a director of Petrolite Corporation, Ltd.

York Is Advertising Manager of Clark Bros.

John L. York has been named advertising manager of Clark Bros. Company, Olean, New York, where he will have headquarters.

Explosion Prevention In Handling Butadiene

Methods of preventing explosions in butane-air mixtures is the subject of Report of Investigations 3691, "The Prevention of Butadiene-Air Explosions by the Addition of Nitrogen and Carbon Dioxide." The report was made following experiments at the Pittsburgh laboratory of United States Bureau of Mines by G. W. Jones and R. E. Kennedy. It is another in the series of investigations on methods of avoiding loss of life and property and was made because of the use of butadiene in the synthetic-rubber industry.

It contains tables to show how much nitrogen and carbon dioxide must be added to make varying mixtures of butadiene and air non-explosive. If nitrogen is used at least 19.6 volumes must be added to each volume of butadiene in order to render all mixtures non-inflammable with air. Only 12.1 volumes of carbon dioxide are necessary under similar conditions.

A copy of the report is available through the United States Bureau of Mines, Washington.

MERIT AWARDS

Awards of merit have been made by the government to the following firms:

The Union Boiler and Manufacturing Company, Lebanon, Pennsylvania, Army-Navy E for high achievement in war production.

De Laval Steam Turbine Company, Trenton, New Jersey, second renewal of right to fly the Navy E flag with two white stars, as a symbol of excellence in production.

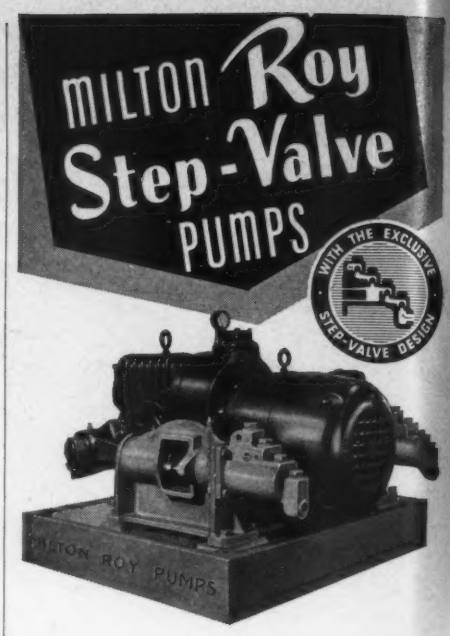
Foster Wheeler Corporation's Carteret, New Jersey, plant, fifth renewal of right to fly the Army-Navy E with two stars. The Dansville, New York, works has received two awards, making a total of five.

American Locomotive Company, Latrobe Plant, New York, Army-Navy E for high excellence in production of war materials.

Alloy Steel Products Company, Linden, New Jersey, Army-Navy E, for excellence in production of war equipment.

Wm. Powell Company, Cincinnati, Ohio, Army-Navy E for outstanding achievement in production of war materials and equipment.

Security Engineering Company, Whittier, California, addition of the gold star to the Maritime M Pennant, for continued meritorious production of vital war material.



Save Their Cost in a Few Months...

Deliver Liquids in Precisely-Controlled Volume

They perform, dependably, with little or no operating attention . . . save labor and maintenance costs. They deliver liquids in *precisely-controlled volume,* down to one pint or less per hour . . . prevent waste, often of very expensive materials. They are rugged, compact, with high volumetric efficiency . . . available in corrosion-resistant metals for practically all chemical processing applications.

Use Milton Roy Pumps for handling

- **TREATING CHEMICALS**
- **INTERMEDIATES**
- **DISTILLATES**
- **TARS AND ASPHALTS**
- **PROPANE AND BUTANE**

and other refinery purposes, including hydrostatic testing and high pressure catalysis, at pressures up to 20,000 psi.

The Step-Valve is an exclusive feature, basic in all Milton Roy Pumps. It is non-clogging, self-cleaning . . . handles solids in suspension, acid sludge, etc., as efficiently as light fractions. It has no pockets in which air-bubbles can form . . . air-binding is impossible. Wire-drawing is eliminated. Valves may be jacketed for temperature control.

Send for Catalog and Bulletins . . . with descriptions of the Step-Valve, the Milton Roy mechanisms for precise stroke adjustment and other features.

Wire or 'phone if we can help in your war effort.

MILTON Roy PUMPS
1383 E. MERMAID AVE., CHESTNUT HILL, PHILA., PA.